2 mip

GCA-TR-73-6-N

INVESTIGATION OF THE D AND E REGIONS OF THE IONOSPHERE

R. N. Kelly
A. Engelman
A. E. Tobey

(NASA-CR-136941) INVESTIGATION OF THE D AND E REGICNS OF THE IONOSPHERE Final Report (GCA Corp.) ~~116~~ 110 p HC $9.00 CSCL 04A

N74-17109

Unclas

G3/13 16031

Prepared for
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WALLOPS STATION
WALLOPS ISLAND, VA.

FINAL REPORT
CONTRACT NO. NASW-1994

November 1973

GCA/TECHNOLOGY DIVISION
BEDFORD, MASSACHUSETTS 01730

GCA-TR-73-6-N

INVESTIGATION OF THE D AND E REGIONS OF THE IONOSPHERE

R.N. Kelly
A. Engelman
A.F. Tobey

by

GCA CORPORATION
GCA TECHNOLOGY DIVISION
Bedford, Massachusetts

FINAL REPORT

Contract No. NASW-1994

Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WALLOPS ISLAND
Virginia

November 1973

TABLE OF CONTENTS

SUMMARY

This report gives details of an experimental program that investigates the ionosphere using sounding rockets. The investigation is part of a continuing program funded by NASA to gather data on the D and E regions of the ionosphere during periods of recurring natural phenomena that influence these regions. To achieve these ends, four vehicles were launched during the eclipse of the sun on March 7, 1970. Other vehicles totalling 10 in all were launched to investigate transient phenomena such as the sporadic E layer. The objectives of each flight and the results achieved are contained in appendices to this report.

SECTION I

INTRODUCTION

The work under this contract was part of a continuing effort funded by NASA to investigate the ionosphere using instrumented sounding rockets. The time period covered by this contract ran from 1 October 1969 to December 1973, during which time 15 payloads were fabricated, 14 of which were successfully launched. The remaining payload NIKE-APACHE 14.511 was rescheduled to be launched at some future date. All payloads were launched from the Wallops Island facility.

Table 1, page 8 of this report lists the launch vehicles and gives date, time and place of launch.

The period covered by this contract saw the transfer of responsibility for the program from NASA GSFC to NASA WALLOPS ISLAND. The smooth transition reflected the admirable cooperation between all parties concerned.

Planning and execution of the program was conducted in cooperation with the Aeronomy Laboratory, University of Illinois represented by S.A. Bowhill and later by L.G. Smith.

SECTION II

EXPERIMENTAL PROGRAM

The subject contract was formalized during discussions held in the last week of December 1969. NASA Headquarters assigned the contract number NASW-1994 and a retroactive start date of 1 October 1969 was agreed upon.

It had been agreed during a meeting held on August 26, 1969, that six payloads were to be flown on NIKE-APACHES boosters. The payloads were designated 14.435 UI through 14.440 UI. Five vehicles were designated launch vehicles, the remainder being a backup vehicle. Launch data for four vehicles was selected as 7 March 1970 to coincide with the sun eclipse. One vehicle was scheduled for launch at 15.45.0 followed by three vehicles at 18.37.2, 18.38.1 and 18.40.0 all times being internationally referenced. The payload configuration for the first four vehicles and a backup vehicle was to be essentially the same as previously flown experiments, designed to investigate the D and E regions of the ionosphere. Instrumentation consisted of a DC/LANGMUIR probe, a two-frequency propagation experiment; UV and X-ray experiments and a mass spectrometer. The overall payload structure is 74 inches long. The tip is insulated from the rest of the structure by a ceramic insulator to accommodate the Lanmuir probe. The first cylindrical section is about 12 inches long and constructed of fiberglass. This section houses the ferrite receiving antennas. Standard GCA doors fit aft of the fiberglass section. The doors, on release, expose the X-ray counter, the solar aspect sensor, and the UV sensors. A magnetometer to generate spin data completes the instrumentation. Turnstile antenna are mounted below the instrument package, which in total weighs 58 lb.

The telemetry details were changed to incorporate a Dorsett transmitter. GCA had flown five similar systems, all successfully, and considered the instrument to be sounding rocket qualified.

The last payload designated 14.440 was scheduled for launch in July 1970. The instrumentation of the payload was similar to the 14.439 but its objective was to measure the sporadic effects in the E region.

A Flight Readiness Review meeting fot the first five payloads was held at NASA/GSFC on January 22, 1970 with Miss E.C. Pressly as chairwoman. The discussions were brief since the experiments and construction of the payloads were familiar to most of those present at the meeting. The only concern expressed was that of using the Dorsett transmitter, this being GSFC's first encounter with this piece of equipment. E. Bissell of GSFC recommended that the performance characteristics of the transmitter be carefully checked over the full temperature range specified. At the conclusion of the meeting, all five payloads were approved for flight.

Four payloads were launched as scheduled during the solar eclipse on March 7, 1970. All four vehicles gave indications of normal launch and operation, the fifth (backup) vehicle was not required.

Trajectory data from one vehicle (14.437) was not obtained, but sufficient information was obtained from the payload altitude switches to compute the trajectory using the time-of-flight method.

A meeting was held at the University of Illinois on April 14, 1970 to firm up plans for the launch of the remaining payload in this series (14.440), and to discuss the disposition of the unused backup payload. It was mutually agreed that the 14.440 payload would be launched as planned on July 14, 1970, with the recommendation that the launch vehicle be changed to a NIKE-CAJUN rather than the originally planned NIKE-APACHE, this would result in a slower velocity at the altitude at which the sporadic E layer was expected to be found. Those present (S.A. Bowhill, E.A. Mechtly, C.F. Sechrist and L.G. Smith) agreed on the change, to be coordinated by L.G. Smith, through the Sounding Rocket Branch of GSFC.

It was further agreed that the backup payload would launched in January 1971 to examine the normal D region, and plans for this were to proceed.

A Flight Readiness Review meeting was held at the Sounding Rocket Branch of NASA/GSFC on June 9, 1970 with Miss E.C. Pressley in the chair. The NIKE-CAJUN vehicle allocated for launch had been given the designation 10.320 with a tentative launch data of 14 July 1970. The payload for this vehicle had previously undergone environmental tests at the Wallops Island facility, during which a boom deployment assymetry was noted. The cause of the malfunction was discovered and corrected, and the payload accepted, subject to successful completion of a rerun of this particular test, scheduled for the following week.

It was also noted at this meeting that the transmitter frequency used in the eclipse operation was not standard for the Wallops Island launch facility and a directive was issued to change transmitters.

NIKE-CAJUN 10.320 was launched from Wallops Island on July 16, 1970 into an intense sporadic E layer. The launch vehicle performed normally, and all experiments were successful. This vehicle completed the field work of the 1-318 contract pending the final disposition of the remaining backup vehicle (14.439). Although a January 1971 launch date had originally been planned for this vehicle, it was apparent that a more realistic data of July 1971 would have to be considered since no contractual coverage had been initiated as of July 1970. In view of this, a request from Professor S.A. Bowhill of the University of Illinois to borrow the payload and Eclipse Launch Console to display at the National Electronics Conference to be held in Chicago during December 1970 was agreed to.

During the month of September 1970, a comprehensive report was prepared by GCA that gave a preliminary evaluation of the results achieved from the five rockets launched. The subject report is appended in Appendix A to this report for the sake of completeness.

The disposition of the backup vehicle was resolved when an extension to the contract was granted on April 23, 1971. The extension called for the reconfiguration of the backup payload plus the fabrication of three additional NIKE APACHE TYPE A payloads, and two TYPE B payloads. Three payloads were tentatively scheduled for launch from Wallops Island late July or early August 1971. These payloads were designated 14.475, 14.476 and 14.477. The three remaining payloads were tentatively scheduled for launch in January 1972, therefore the field tasks covering these launches were not included in the referenced contract extension.

The Mission Readiness Review for three payloads 14.475, 6 and 7, was held at Wallops Island on 16 July, 1971 with Mr. Harvey C. Needleman as chairman. The only concern of the panel was the anticipated spin rate deviation associated with the Apache vehicle. It was recommended that the fin wedges be redesigned to limit the spin rate to a value not to exceed the design value of 7.5 R.P.S. With that in mind all three vehicles were accepted for flight.

All three payloads were launched from Wallops Island on the morning of August 20, 1971. The launch was normal on all three boosters. A loss of telemetry was experienced by 14.475 and 14.476 at an altitude of 70,000 ft. on the downward leg of the trajectory. Since this was near the end of the programmed flight, it was assessed that the scientific objectives had been attained.

A report summarizing the data obtained from these launches is included in this final report as Appendix B.

A project initiation conference was held at Wallops Island on November 2, 1971 to discuss a further extension of the contract to fund the launching of the three remaining payloads Mr. R.L. Kingman as chairman. It was agreed that the three payloads will be delivered to Wallops Island on January 3, 1972 and the launches will take place some time after the 17th of that month.

At this juncture in the program, it was deemed advisable to write a comprehensive report on the activities covering the period October 1, 1970 to September 30, 1971, and that report is incorporated into this final report as Appendix C.

Change Order #3 to the contract was signed on the 4th of April 1972 to extend the contract through December 31, 1972.

NIKE APACHE 14.440 was launched from Wallops Island on the 31st of January 1972. The vehicle and payload performed well, with the exception of some high voltage breakdown in the GEIGER counter experiment. This launch was part of a series of 3 launches all of which were scheduled to have been launched early January. Adverse climatic conditions forced the postponement of the remaining two vehicles, which were returned to GCA for storage.

A comprehensive technical report was prepared by GCA covering the period 1 May 1972 to 31 July 1972 that gave details of the NIKE APACHE 14.440 flight, and that document is contained in this final report as Appendix D.

NIKE-APACHE payload 14.439 was shipped to Wallops Island on August 21, 1972 for pre-launch testing. The tests were completed on August 25th. During the thrust axis phase of the vibration test, the 40 KHz vco exhibited a 20 db decrease in amplitude from its specified output. This vco was replaced and the remaining tests were completed satisfactorily.

The mission Readiness Review meeting was held on August 30, 1972, and the payload accepted for flight.

A Project Initiation Conference for the Winter Anomoly Program, was held at Wallops Island on September 21, 1972. The object of the program was defined as the successful launch of a TYPE A MOD 7 payload at each of 3 designated days. The payloads were designated 14.509, 14.510 and 14.511. Testing of the payloads was tentatively scheduled for October 1972 and launch scheduled for December 1972.

NIKE-APACHE 14.439 was launched from Wallops Island on the night of November 1, 1972. The launch was successful and a report giving the results obtained is attached to this report as Appendix E.

Fabrication of the 3 NIKE-APACHE payloads designated 14.509, 14.510 and 14.511 was completed in October 1972. All three payloads were delivered to Wallops Island during the first week of November. A Mission Readiness Review was held on November the 20th 1972 and all payloads were accepted with the proviso that one of the vco units in payload 14.511 be subjected to a vibration test.

Payload 14.509 was successfully launched on the 5th of December and payload 14.510 was successfully launched on the 16th of January 1973.

The schedule for completion of the two remaining payloads was changed by a contract change modification issued January 19th 1973, by which change the delivery of both payloads was rescheduled to April 30, 1973. The payloads were completed on schedule and transferred to the University of Illinois along with other government furnished equipment appropriate to the contract, on April 30th 1973. This action substantially completed the effort of GCA under the existing contract, the one remaining task was that of providing field support for the future launches. Payload 14.513 was launched from Wallops Island on August 3, 1973 and payload 14.514 was launched on August 10. The final technical reports for these payloads will be prepared by the University of Illinois, it is considered therefore that this report fulfills GCA's contractual requirements of writing the Final Technical Report.

Table 1. Rocket Launches, Contract NASAW - 1994

NIKE-APACHE	TIME*	DATE
14.435	15.45.0	7 March 1970
14.436	18.37.2	7 March 1970
14.437	18.38.1	7 March 1970
14.438	18.40.0	7 March 1970
14.475	09.19.0	20 August 1971
14.470	09.44.0	20 August 1971
14.477	10.14.0	20 August 1971
14.440	17.30.0	31 January 1972
14.509	17.30.0	5 December 1972
14.510	17.30.0	16 January 1972
14.511	NOT LAUNCHED	
14.439	05.03.0	1 November 1972
14.513	16.00.0	3 August 1973
14.514	15.04.0	10 August 1973
NIKE-CAJUN	**TIME***	**DATE**
10.320	16.00.0	16 July 1970

* AT ALL TIMES QUOTED ARE UNIVERSAL TIME

SECTION III

ABSTRACTS OF PAPERS PUBLISHED

The following papers were published giving results of scientific findings on this program. An abstract of each paper is given on subsequent pages.

1. Rocket observations of solar UV radiation during the eclipse of 7 March 1970

2. Rocket observations of solar x-rays during the eclipse of 7 March, 1970

3. Electron Loss Coefficients for the D-Region of the Ionosphere from Rocket Measurements During the Eclipses of March 1970 and November 1966

4. Rocket observations of sporadic-E layers

Rocket observations of solar UV radiation during the eclipse of 7 March 1970

L.G. Smith

GCA Technology Division, Bedford, Massachusetts 01730 U.S.A.

Abstract - Photometers sensitive to narrow bands of radiation at Lyman-α (1216Å) and 2600Å were included in the payloads of four Nike Apache rockets flown from Wallops Island before and during the eclipse. At the center of totality the flux of Lyman-α from the solar corona is 0.15 percent of the flux from the unobscured sun. The flux at second contact is 0.64 percent; at third contact, two observations give 0.52 and 0.59 percent. The brightness of the chromosphere in Lyman-α decreases exponentially over the range 5 to 30 arc-sec from the limb with a scale height of 3835 ± 70 km. In addition to the coronal and chromospheric Lyman-α a diffuse source is found. This is restricted to within 20° of the earth's horizon and is nearly uniform in azimuth. At 170 km the flux is about 3 percent of that from the unobscured sun. The flux of Lyman-α during the eclipse is considered in relation to the observed variation in electron density. It is concluded that, in totality, the ionosphere near 80 km is not in equilibrium with the ionizing radiation and that the production rate for electrons is not negligible if the loss process is recombination; it is negligible if the loss process is attachment-like.

Accepted for publication in Journal of Atmospheric and Terrestial Physics.

Rocket observations of solar x-rays
during the eclipse of 7 March, 1970

C.A. Accardo, L.G. Smith, and G.A. Pintal
GCA Technology Division, Bedford, Massachusetts 01730

Abstract - The absorption profiles and residual fluxes of three bands of solar x-rays have been measured before and during the eclipse of 7 March 1970 at Wallops Island. In the bands 2-8Å, 8-20Å and 44-60Å the residual flux in totality is found to be respectively 5, 7 and 16 percent of the flux from the uneclipsed sun. It is shown that the radiation maintaining the E layer varies in proportion to the 44-60Å flux. In the D layer, ionization by the residual flux of 2-8Å is less important in totality than is ionization of nitric oxide by Lyman-α.

Accepted for publication in Journal of Atmospheric and Terrestrial Physics.

Electron Loss Coefficients for the D-Region of the Ionosphere from Rocket Measurements During the Eclipses of March 1970 and November 1966

E.A. Mechtly and C.F. Sechrist, Jr.

Aeronomy Laboratory
University of Illinois
Urbana, Illinois 61801

L.G. Smith

GCA Technology Division
GCA Corporation
Bedford, Massachusetts 01730

Abstract

Recombination-like electron loss coefficients measured during the March 1970 eclipse coincide with those from November 1966 eclipse and range from 2×10^{-7} cm^3 s^{-1} at $Z_o + 6$ km to 5×10^{-5} cm^3 s^{-1} at $Z_o - 2$ km, where Z_o is the altitude of the steep gradient of electron concentration. During totality; Z_o was 82.5 km in 1970, and 86.8 km in 1966. For full-sun conditions, Z_o was 84 km on both eclipse days. Attachment-like electron loss coefficients from both eclipses are in good agreement below Z_o, and have a nearly constant value of about 8×10^{-3} s^{-1}. Below Z_o, attachment-like loss rates agree with production rates, i.e., electron concentration is proportional to electron production.

Accepted for publication in Journal of Atmospheric and Terrestrial Physics.

Rocket observations of sporadic-E layers

L.G. Smith
GCA Technology Division, Bedford, Massachusetts 01730
E.A. Mechtly

Aeronomy Laboratory, Department of Electrical Engineering
University of Illinois, Urbana 61801

Abstract

The characteristics of mid-latitude sporadic-E layers have been observed using rocket payloads incorporating a probe and a propagation experiment. Layers below 120 km show evidence of preferred altitudes. The slopes of layers are within one degree of horizontal. The horizontal dimensions are deduced to be several hundred kilometers. Individual profiles of daytime layers show a range of shapes ranging from triangular to rectangular. The plasma frequency derived from the peak electron density in the layer is found to agree with the blanketing frequency given by the local ionosphere sounder.

Accepted for publication in Radio Science.

APPENDIX A

I. INTRODUCTION

The period reported here has included the successful completion of the flight program. Five Nike Apache rockets have been launched. As indicated in Table 1 four were launched on the day of the total solar eclipse of 7 March 1970 and one, later in the summer, into a daytime sporadic-E layer. All launches were from Wallops Island. An additional payload was fabricated for the eclipse operation and was, with its rocket, on a launcher during the eclipse operation. This back-up rocket, Nike Apache 14.439 was not launched because of the success of the four prime vehicles. It is planned to save it for use during proposed extension of the program (GCA proposal number 4248-6-01).

The next section of this report contains a description of the eclipse operation, including a preliminary evaluation of the success of the individual experiments. The third section contains a description of the experiment developed for the measurement of the electric field in a sporadic-E layer, details of the launch operation and preliminary comments on the data.

The fourth section contains a description of a new method of processing data from the solar aspect sensor which has considerably improved the accuracy of the measurement and, consequently, has improved the quality of data from the solar radiation experiments. A modification to the solar aspect sensor used on the payload of the sporadic-E experiment is also noted.

Table 1: Rocket Launches, Contract NASW-1994

Vehicle*	Time LST	Date	Place**	Remarks
14.435	1045	7 Mar 1970	W.I.	Pre-eclipse
14.436	1337:10	7 Mar 1970	W.I.	Eclipse
14.437	1338	7 Mar 1970	W.I.	Eclipse
14.438	1340:40	7 Mar 1970	W.I.	Eclipse
10.320	1100	16 Jul 1970	W.I.	Sporadic-E

*Prefix 14. = Nike Apache, 10. = Nike Cajun
**W.I. = Wallops Island, Virginia (37.84°N, 75.48°W)

II. ECLIPSE OPERATION

The detailed circumstances of the total solar eclipse of 7 March 1970, in the vicinity of Wallops Island were presented in the previous report. The launch site itself is just inside the northern limit of the path of totality. A lower-than-usual launch angle (74.5^{o}) was required to ensure that the Nike Apache vechicles were well inside totality while passing through the D region. The time of mid-eclipse at the launch site was 1837:53 UT.

The scientific objectives of the flights, also described in the previous report, required the launch times and trajectories to be chosen as follows:

1) Nike Apache 14.435: to be launched on the morning of the eclipse, at the time having the same solar zenith angle (47^{o}) as at totality. The azumuth of 110^{o} was specified to give the solar radiation sensors a favorable view of the sun.

2) Nike Apache 14.436: to be launched so that is passed through the D region at the beginning of totality (second contact). The azimuth angle for this and the next two vehicles was chosen as 135^{o}.

3) Nike Apache 14.437: to be launched so that is passed through the D region, near the center of totality, 50 seconds after second contact.

4) Nike Apache 14.438: to be launched so that it passed through the D region, about 90 seconds after the end of totality, with about 1.5 per cent of the solar disc visible.

The launch selected to meet these criteria were the actual launch times, given in Table 1.

The eclipse circumstances have been calculated for the three rocket flights are shown in Figure 1. The trajectory used for Nike Apache 14.437 is provisional, as discussed below. Nike Apache 14.436 was technically outside the shadow up to an altitude of 121 km. At the maximum distance from the umbra, at 79 km altitude, this rocket is 4.2 seconds before second contact with 0.014 per cent of the disc visible. This rocket passed out of

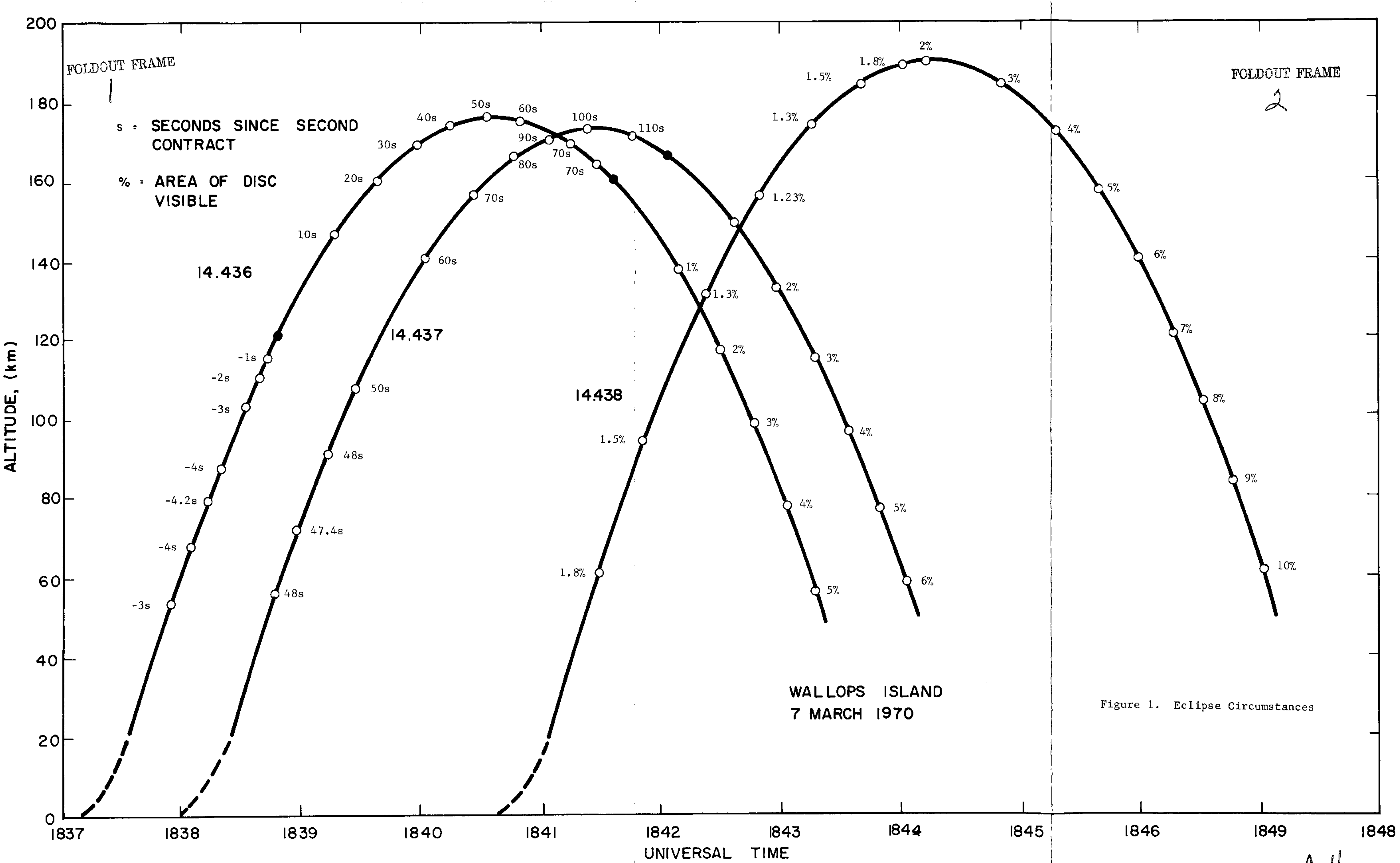


Figure 1. Eclipse Circumstances

the shadow at an altitude of 160 km on descent. Nike Apache 14.437, launched 50 seconds later, follows nearly the same trajectory. In the D region the ionosphere has been in totality for 48 seconds. This vehicle went out of the shadow at an altitude of 166 km, shortly after passing its apogee. The third rocket, Nike Apache 14.438, passed through the D region with between 1.8 and 1.5 per cent of the disc visible. At 80 km the time elapsed since third contact is about 110 sec. This rocket came closest to the shadow axis at an altitude of 156 km, on ascent, where 1.23 per cent of the disc was visible. It thus appears that all three rockets in and near totality achieved the required eclipse circumstances.

Times of various events in each flight are given in Table 2. As noted before, the four vehicles were launched at the pre-selected times. The ignition of the second stage, nominally occurring at 20 seconds after launch, was observed to be between 21.7 and 22.2 seconds after launch. Calibration signals were applied to the experiments in the period between actuation of the 40 and 70 Kft baroswitchs, for about 9 seconds on ascent and about 5 seconds on descent. Door ejection occurred at an altitude of about 50 km; the 70 kft baroswitch on ascent arms the dual-electronic timer having a 15 second delay. Good quality telemetry signals were obtained throughout the flights.

Vehicle performance data aregiven in Table 3. The apogee of 14.435 is close to the predicted value (184 km), corresponding to the effective launch elevation of 78 deg. The apogees of 14.436 and 14.438 are higher than the predicted value (167 km), which was based on an effective launch elevation of 74.5 deg. The flight azimuth of Nike Apache 14.436 is exactly

Table 2: Events Determined From Telemetry Records

Events (UT)	14.435	14.436	14.437	14.438
First Stage Ignition	1545:00.1	1837:10.1	1838:00.1	1840:40.1
40 kft Baroswitch on	1545:20.5	1837:29.7	1838:20.5	1840:59.7
Second Stage Ignition	1545:22.1	1837:31.8	1838:22.3	1841:02.1
70 kft Baroswitch on	1545:29.2	1837:38.9	1838:29.6	1841:08.3
Door Ejection	1545:43.5	1837:54.2	1838:45.2	1841:23.2
70 kft Baroswitch off	1551:47.2	1843:44.7	1844:32.7	1847:30.4
40 kft Baroswitch off	1551:52.0	1843:49.6	1844:37.8	1847:33.8
Loss of Signal	1552:00.5	1843:58.7	1844:46.4	1847:44.3

Table 3: Vehicle Performance

		14.435	14.436	14.437	14.438
Apogge, km		184.4	175.7	173**	189.4
Flight azimuth*, deg		117	138	-	141
Spin rate*, rps		6.8	6.1	7.9	8.8
Precession Cone	Period, sec	34.2	38.8	30.0	27.0
	Half-angle, deg	12.6	9.2	2.4	5.0

*Measured at apogee
** Estimated

as predicted; the other two for which radar data are available are satisfactorily close to the predicted values.

The spin rates, measured at apogee but essentially constant while the rocket is above an altitude of almost 100 km, fall within the design range of 6 to 9 rps. The precession cone periods and half-angles are typical of previous Nike Apache flights with similar payloads.

A complete radar track was obtained on 14.435 from launch to impact. The track on 14.436 is nearly complete, ending at an altitude of 45 km on descent. No track was obtained for 14.437; the assigned radar was found later to have followed another vehicle. The radar track for 14.438 ends at an altitude of 170 km, after apogee. It has been extrapolated down to 50 km altitude.

A trajectory for 14.437 has been generated at the Sounding Rocket Branch, NASA/GSFC based on the following information. The most probable value of apogee has been derived from the switching times of the 70 kft baroswitches. If τ is the elapsed time between the switching on ascent and descent, the apogee altitude z is given by

$$z = z_o + \frac{1}{2} g \left(\tau/2\right)^2$$

where z_o is the altitude of the baroswitch actuation. Since g cannot be assumed constant over an altitude range of two hundred kilometers the formula is used empirically over a limited range of values of z and τ by curve-fitting. For the three flights 14.435, 14.436 and 14.438 the following relation is obtained by the method of least squares:

$$z = 30.3 + 1.085\ 10^{-3}\ \tau^2$$

with z in km and τ in sec.

This gives for 14.437 an apogee altitude of 173.3 km. The values for the four flights and the relation are shown in Figure 2.

Given the apogee altitude and the times and altitudes of the 70 kft baroswitches a trajectory can be fitted to within 1 km in altitude. This is accurate enough for some purposes but, particularly for the important study of the detailed changes of the D region, an accuracy of better than 0.1 km is required. Fortunately, in the probe current profiles from 14.436, 14.437 and 14.438 an ionospheric feature near 96 km, of the nature of a small sporadic-E layer, is easily identified. As indicated in Table 4 the height decreases by 0.15 km in the intervals between 14.436 and 14.438 and, by linear interpolation the altitude is estimated to be 95.85 km at the time that it was penetrated by 14.437. This one point can now be used to adjust the trajectory of 14.437 to bring it into exact agreement with 14.436 and 14.438 at least in the upper D region.

There is no direct information available on the flight azimuth or horizontal velocity (or range) for 14.437. Since 14.436 and 14.437 were launched only 50 seconds apart and on adjacent identical launchers it has been assumed that the launch azimuth of 14.437 is the same as that of 14.436. With respect to horizontal range, the method adopted by the Sounding Rocket Branch has been to calculate an effective launch angle, using 14.436 as a guide, to produce a fit in altitude and then compute the horizontal motion. A trajectory derived according to this method has been used in calculating the eclipse circumstances of Figure 1. A further check of the computer - generated trajectory will be made by comparsion of the 2600A and Lyman-α data from 14.436 and 14.437 and further adjustment made, if required.

Table 4: Ionospheric Feature at 96 km

	UT	Altitude
14.436	1838:27.85	95.90
14.437	1839:18.88	(95.85) by interpolation
14.438	1841:55:00	95.75

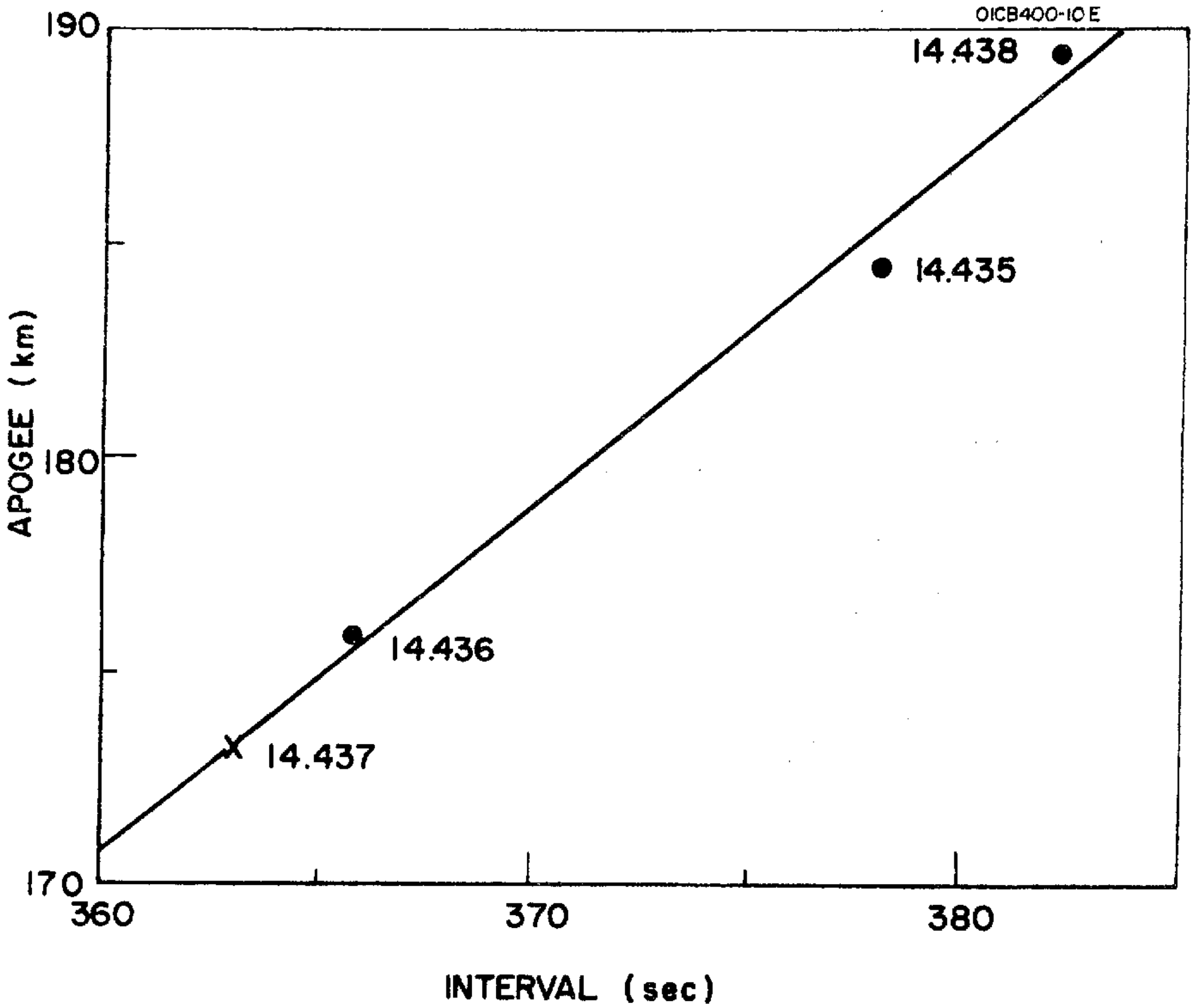


Fig. 2. Estimate of Apogee Altitude of Nike Apache 14.437 Based on Time Interval of 70 kft Baroswitch

The data from the several instruments carried in each of the four payloads are of excellent quality and are being processed. The probe current data have been forwarded to the Aeronomy Laboratory, University of Illinois, to where they will be combined with the data of the propogation experiment to give electron density profiles. It is already clear that the very low values of electron density at altitudes below 75 km occur in all three profiles; this is unexpected, particularly in the profile from 14.438, obtained about 110 seconds after the end of totality, with more than 1 per cent of the disc visible. It had been anticipated that this profile would show the partial recovery of the lower D region.

The next important observation for which data has been obtained concerns the ozone concentration. It is predicted on photochemical theory that during the eclipse there will be an increase in ozone concentration at altitudes above 60 km. The 2600A photometer was included in the payload of 14.438 primarily for this experiment. The method of absorption spectroscopy is used. A complication in this instance is the change in eclipse circumstances during the flight. It is not possible to make the assumption of a constant incident flux. The incident flux (or, at least, a relative value) must be obtained during the period the ozone absorption is being observed. In the analysis now being done use is made of the fact, illustrated in Figure 1, that the region of interest, 50 to 90 km, can be matched, in area of solar disc, by corresponding altitudes which are well above the absorbing region of the atmosphere. For example, 1.8 percent of the disc is visible at altitudes of 61 km and 188.5 km. The ratio of signal at the two altitudes gives the transmission factor. The analysis then follows the procedures appropriate to a constant incident flux.

The Lyman-α photometers also were carried on all four payloads. The primary purpose on the pre-eclipse launch is the determination of the concentration profile of molecular oxygen which is used in deriving values of electron collision frequency. In the two launches in totality there are different objectives. The first is the determination of residual flux of Lyman-α which is the principal source of ionization in the upper part of the D region. The second objective is the determination of the brightness distribution of Lyman-α in the chromosphere. The data show clearly (as expected) that the diameter of the shadow for the chromosphere is smaller than that for the photosphere, as represented by the 2600A radiation.

The detectors for solar X-rays in the wavelength range 44-60A (Geiger counters with windows of 1/4 mil mylar) also performed well in all four payloads. The residual flux above the absorbing region is found to be 11 per cent on 14.437, in the middle of totality, and 15 per cent on 14.438, shortly following totality. The count rates at the top of the atmosphere were high, indicating an X-ray flux from the unobscured sun of the order of 0.2 erg cm^{-2} sec^{-1}. Because of the critical nature of the dead time correction at such high rates additional laboratory tests of X-ray detectors remaining from the eclipse have been conducted. These have used two variations of the method of superposition-of-sources to show that the dead-time correction is valid up to the highest rates observed. The actual value of dead time is 125 μsec.

The absorption profiles obtained on ascent and descent for the four flights show generally good agreement with each other giving additional confidence in the dead time correction. One interesting anomaly in the X-ray data not yet explained is a period of unusually high flux on the detector on 14.438 while the rocket ascended between 105 and 120 km. In the altitude range 110 to 115 km the corrected count rate is about double the value calculated from the atmospheric attenuation of the measured value of the incident flux.

As the comments made above have indicated the performance of both vehicles and instrumentation was uniformly successful. The only blemish, the failure of radar to obtain trajectory information on Nike Apache 14.437, has largely been compensated by the overlap with experiments in the preceding and following vehicles.

The processing of data is continuing with the aim of a presentation of results at the eclipse symposium to be a part of the COSPAR meeting to be held in Seattle, Washington, in May 1971.

III. ELECTRIC FIELD EXPERIMENTS

The explanation of the occurrence of sporadic-E layers in the daytime E region remains one of the major unsolved problems of the lower ionosphere. The vertical transport of ionization caused by the horizontal motion of the plasma in the presence of the geomagnetic field provides a satisfactory explanation for such layers in the nightime ionsophere. It fails for the daytime ionosphere because of the high loss rates corresponding to the now generally accepted value of recombination coefficients, greater than 1×10^{-7} cm^3 sec^{-1}. It also fails to explain the relatively limited vertical extent of the layer (a few km) and the detailed shape of the layer.

In view of the limited information on the characterisitics of sporadic-E layers, other than electron density, an experiment was designed in which the primary objective was the determination of the horizontal component of electric field in an intense daytime sporadic-E layer. The experiment itself is based on the method for electric field measurement developed by Mozer* and by Aggson**. In both, the electric field is measured directly from the difference of potentials of electrodes at the ends of two diametrically opposed booms. The experiment makes use of the spin of the vehicle to develop an AC signal. This mimimizes the effects of fixed off-set voltages such as these resulting from contact potential differences and thermal EMF's. In addition, following Mozer, the electrode are metal spheres coated with colloidal graphite ("Aquadag") which provides a nearly uniform work function over the surface.

The assembly of the payload is shown in Figure 3, with the booms in the folded position. The method of attaching the electrodes to the end

*F. S. Mozer "Instrumentation for measuring electric fields in space" in small rocket instrumentation techniques (ed K.I. Maeda)North Holland, Amsterdam, 1969.

**T. L. Aggson 'Probe Measurements of electric fields in space" in Atmosphere Emissions (ed. McCormac and Omholt), Van Nostrand Reinhold New York 1969.

Page intentionally left blank

of the booms was later modified to that shown in Figure 4 to give better exposure of the spheres. With the booms fully extended the center-to-center distance between the electrodes is 1.661 m.

The booms are retained by a wire which is served by a guillotine cutter shortly after the doors have been ejected. The circuit of the timer for firing the pressure cartridge (Holex 6200) in the door ejection mechanism and, after 0.5 sec delay the guillotine cutter (Holex 2800), is shown in Figure 5. The timers use unijunction transistors to obtain the required delays. The first timer is armed at 70 kft by redundant baroswitches. After the required delay the unijunction transistor (Q1) conducts causing the SCR (Q2) to turn on and energize the relay (K2). This simultaneously applies voltage to the squib, through a current-limiting resistor, and to the second timer. After 0.5 delay derived from a second unijunction transistor (Q4) the second relay (K1) is energized applying voltage to the guillotine cutter, also through a current-limiting resistor. Because of the tendency of the bridge of a guillotine cutter to be a short-circuit after firing, the voltage is removed from the guillotine cutter after a further interval of 0.1 sec. This is accomplished by removing the power from the second unijunction transistor by causing the SCR (Q6) across the input to turn on. A duplicate circuit is connected to the second bridge in each pyrotechnic. The timer monitor signal is combined with the solar aspect signal and telemetered on IRIG Channel 19.

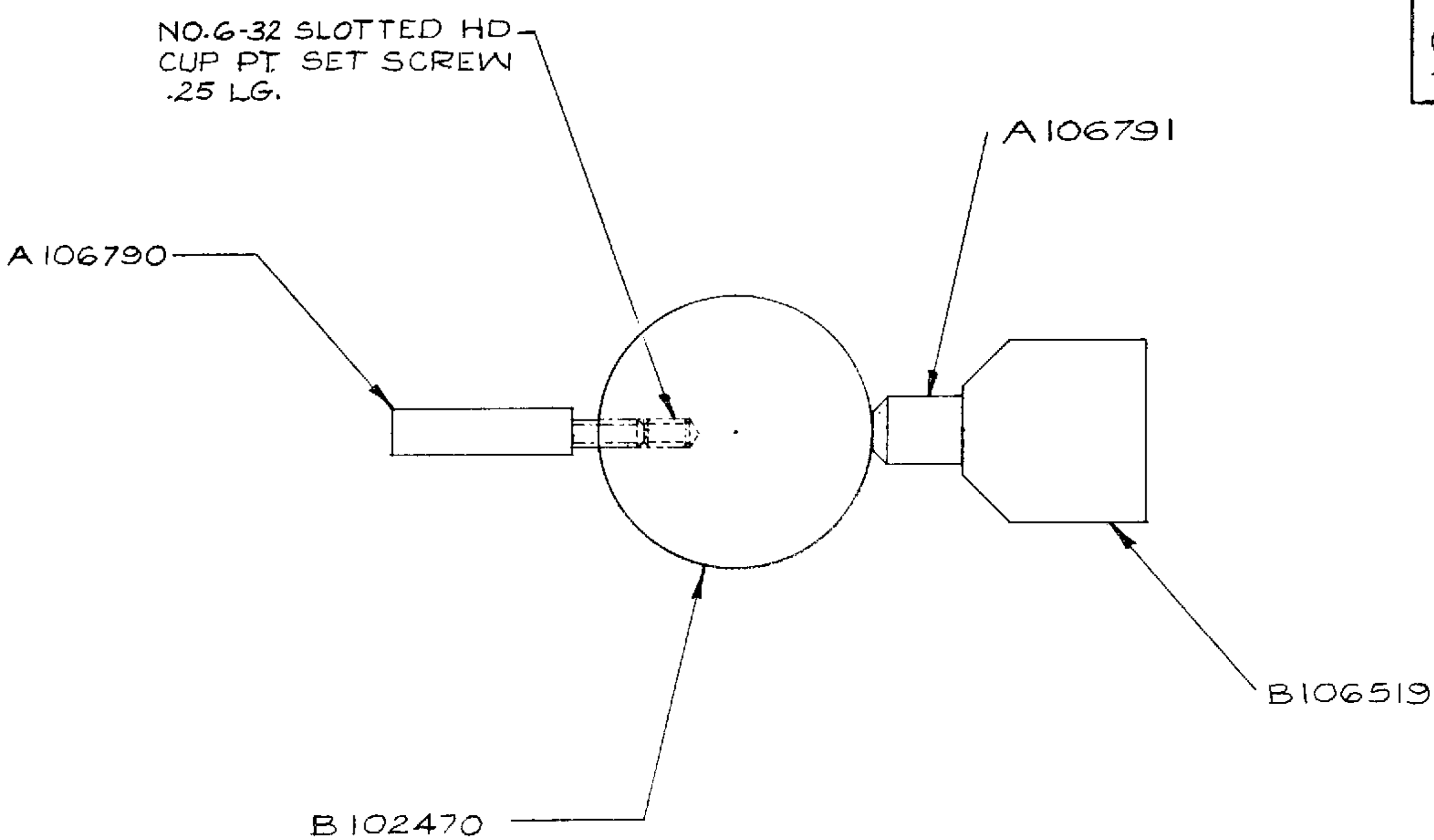
The circuit of the electric field experiment is shown schematically in Figure 6. Each electrode is connected to a voltage follower (Bell and Howell 008A) having a low current off-set ($\approx 10^{-11}$ amp) and a high input impedance ($\approx 10^{+11}$ ohm). The voltage follower also drives the shield of the

FOLDOUT FRAME 1

106793

REVISIONS					
SYM	ECO NO	DESCRIPTION	DATE	CHKD	APPROVED

FOLDOUT FRAME 2



INSERT NO.6-32 SET SCREW, .25 LG INTO HOLE IN SPHERE; NEXT INSERT PROBE EXTENSION ROD WHILE SPHERE IS COATED WITH AQUADAG & THEN MOUNTED ON PROBE HOLDER.
REMOVE EXTENSION ROD; TIGHTEN SPHERE ON HOLDER USING NO. 6-32 SET SCREW. FINALLY SEAL 6-32 HOLE WITH NYLON SET SCREW .25 LONG.

Fig. 4

UNLESS OTHERWISE SPECIFIED ALL DIM. ARE IN INCHES

TOLERANCES

.X ± .06 .XX ± .02 .XXX ± .005

ANGLES ±0°30'

MACHINE FINISH 63 ✓

BREAK SHARP EDGES AND COR. .005 TO .020R APPROX

DR	WFA	DATE 6/1/70
CHK	LGB	6/3/70
APPROVALS		
	LGB	6/3/70
RELEASED		

GCA TECHNOLOGY DIVISION
Bedford, Massachusetts
GCA CORPORATION

TITLE: ELECTRIC FIELD PROBE ASSEMBLY

	1-318	
NEXT ASSY	USED ON	
APPLICATION		

MATERIAL: #

FINAL FINISH: #

SIZE: B | DRAWING NO. 106793

SCALE 1:1 | WT | SHEET 1 OF 1 | REV 0

DO NOT SCALE

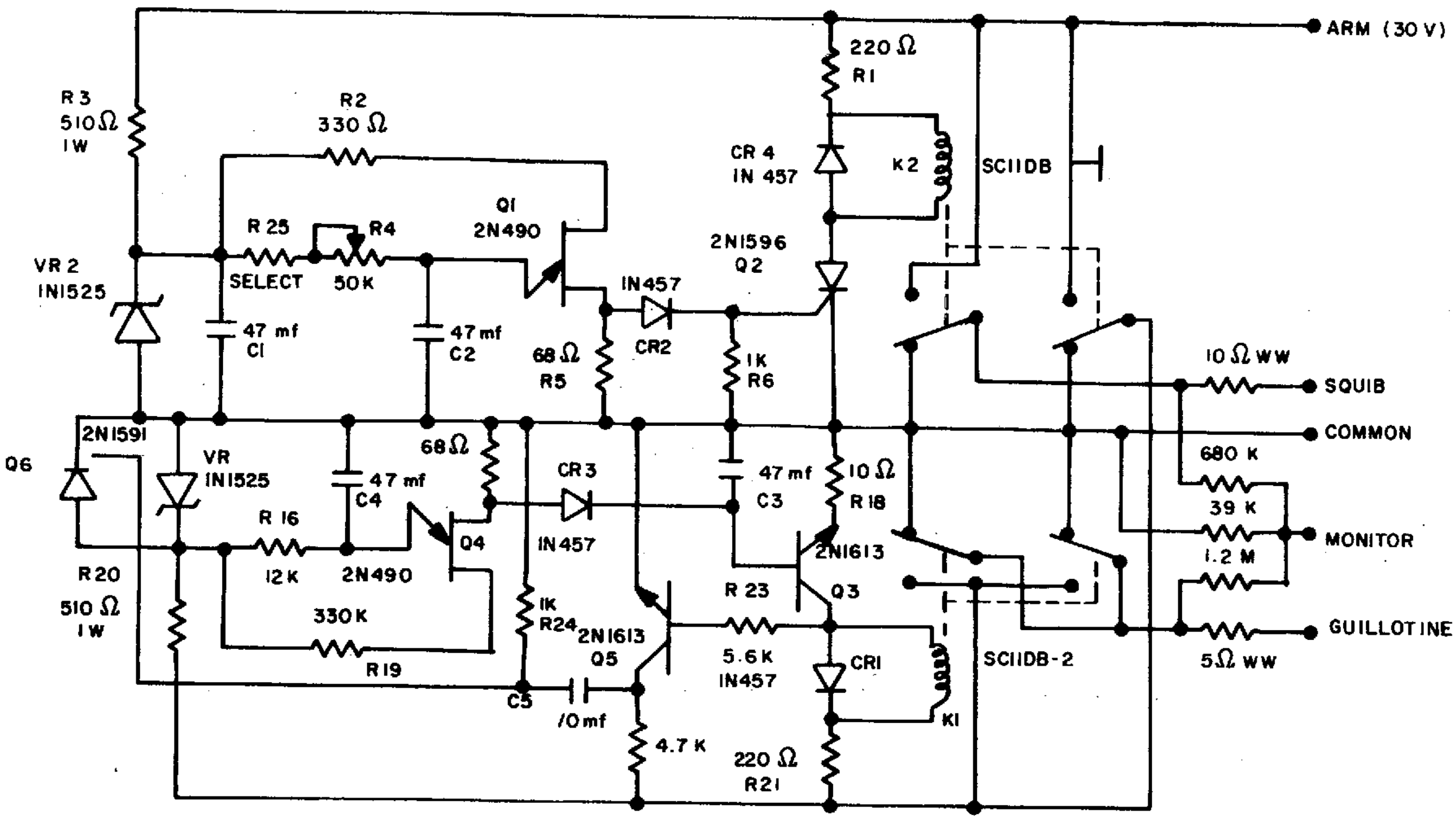


Figure 5. Circuit of Electronic Timer

01CB334-609

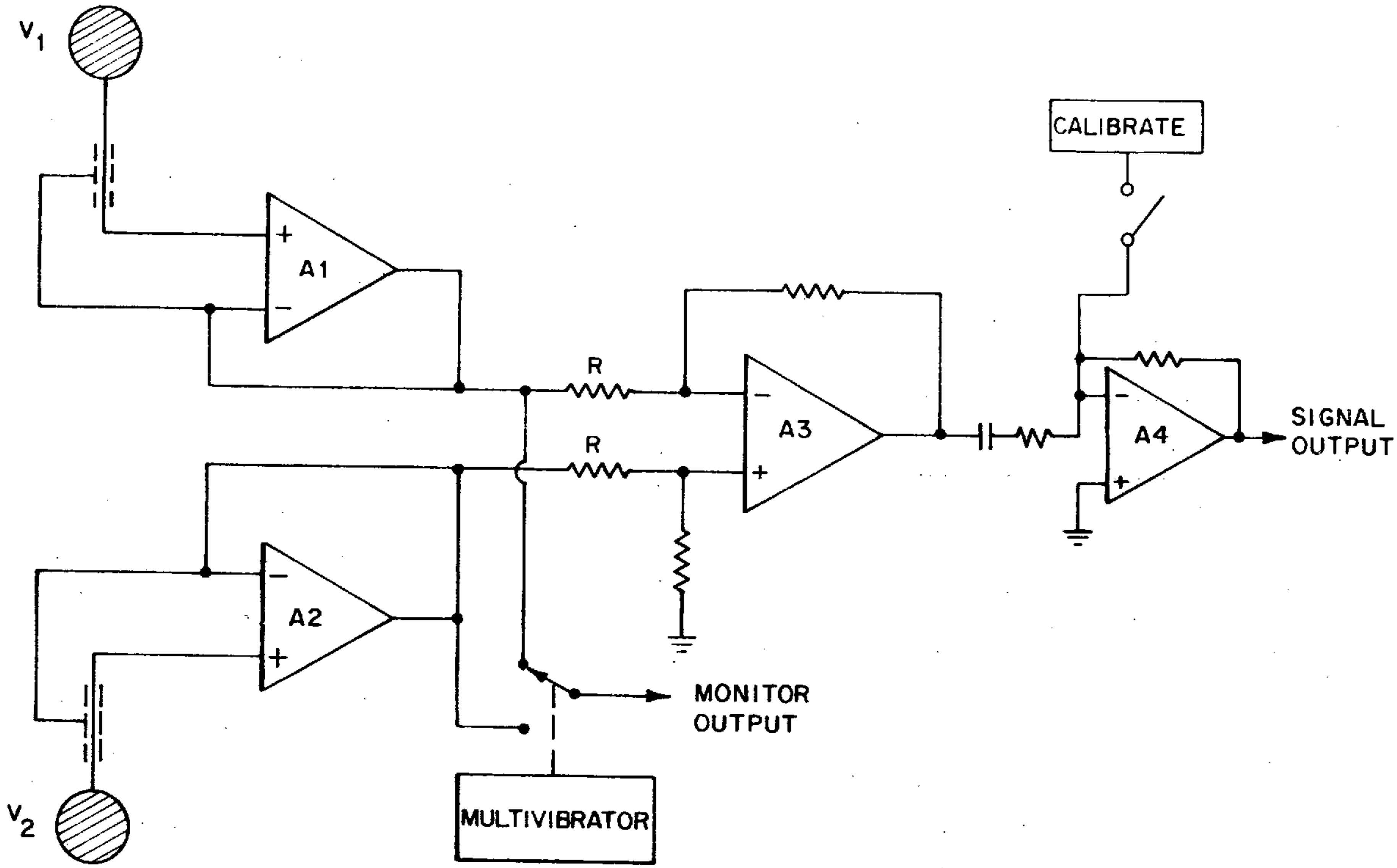


Fig. 6

Electric Field Experiment, Circuit Schematic cable making the connection to the electrodes; thus mimimizes leakage and noise problems. The outputs of the two followers are connected to a unity gain difference amplifier. The output of this is ac coupled to an amplifier with a gain of 20. This signal is then telemetered on IRIG Channel 14.

Additional circuits are included so that 1) the potentials of the electrodes can be measured individually and 2) a calibration signal can be applied during the flight. The monitor signal, telemetered on IRIG Channel 12 is obtained by alternately sampling the outputs of the two voltage followers. The sampling times, 30 m sec and 50 m sec, are unequal to code the separate electrodes. The calibration circuit is activated in the altitude range 40 kft to 70 kft, both on ascent and descent, by baroswitches.

The vehicle selected for this experiment was a Nike Cajun rather than the Nike Apache,which had been used in all preceeding flights of the program. The decision was made on the basis that the maximum altitude of occurrence of daytime sporadic-E layer is about 120 km and there is an advantage in not greatly exceeding this altitude at rocket apogee. The vertical velocity of the rocket in traversing the layer is reduced giving better height resolution in the measurements,and any disturbance of the plasma by the rocket is mimimized.

Nike Cajun 10.320 was launched at 1100 EST (1600 UT) on 16 July 1970. Times of events during the flight and some figures indicating vehicle performance are given in Table 7. The only significant deviation from predicted performance is in the flight azimuth and that favored the experiment.

Table 7: Nike Cajun 10.320, 16 July 1970, Wallops Island

First stage ignition	1600:00.1 UT
Second stage ignition	1600:17.1
40 kft baroswitch on	1600:20.0
70 kft baroswitch on	1600:24.7
Door ejection	1600:53.2
Boom deployment	1600:53.7
70 kft baroswitch off	1605:47.4
40 kft baroswitch off	1605:53.7
Loss of signal	1606:13.5
Spin rate before deployment	5.68 rps
Spin rate after deployment	3.63 rps
Precession cone, period	41.0 sec
Precession cone, half-angle	10.0 deg
Altitude, at apogee	142.8 km
Flight azimuth, at apogee	174.4 deg

It had been desired, in order to mimimize the induced electric field that the rocket velocity vector be as closely as possible aligned with the magnetic field vector as the rocket passed through the sporadic-E layer. At Wallops Island the magnetic field vector has an elevation angle of 69 deg and an azimuth of 171 deg. Range safety considerations limited the launch azimuth to 160 deg but, because of an unexpected change in direction after launch, the rocket actually passed through the sporadic-E layer with its velocity vector having an azimuth angle of 173 deg.

The profile of probe current shows the altitude of the peak of the layer is 102.4 km and the total thickness is 2.3 km. The probe current at the peak of the layer is larger than an interpolated value, representing the ambient, by a factor of 2.8. Using an estimated ratio of probe current to electron density of 10^{-10} amp cm^3 the electron density at the peak of the layer is 2.5×10^5 cm^{-3}. This is equivalent to a blanketing frequency of 4.5 MHz, in good agreement with the value indicated by the ionosonde.

The data from the electric field experiment appear to be of excellent quality but have not yet been processed.

IV. SOLAR ASPECT DATA REDUCTION

The solar aspect angle, i.e. the angle between the spin axis of the rocket and the direction of the sun, is determined by a relatively simple device which uses diamond-shaped aperture mask in combination with a solar cell to generate two pulses during each revolution. The ratio of the interval between the two pulses (T1) and the revolution period (T2) defines the aspect angle.

The time intervals T1 and T2 have previously been measured from chart records. This is adequate for T2 since it normally changes only very slowly during the rocket flight and can be averaged over many revolutions. However, it has been found that measuring the interval between aspect pulses from a chart record the best accuracy that can be achieved in the aspect angle is about 0.5 deg. This has been a limiting factor in the aspect correction of the 2600A photometer data used in determining the concentration profile of ozone. A relatively simple system of electronic measurement has developed which gives a more accurate value of T1 and allows aspect angles to be determined to 0.1 deg.

The leading edges of the two pulses which define T1 are used to generate a start and stop signal, respectively. These gate a digital counter which thus measures the time interval. Most data processing is performed from magnetic tapes (as opposed to real-time, telemetered signals) with the possibility variation in tape speed. This source of error is eliminated by using the 100 kHz reference signal from the tape rather than that from the oscillator contained in the counter. The output of the counter is recorded for consecutive revolutions on a digital printer at a rate equal to the spin rate of the rocket, typically 6 to 9 per second.

The arrangement is shown schematically in Figure 7. The pulse-shaping circuit consists of a Schmidt trigger. This insures a sharp rise time and is also used to adjust the threshold. The pulses are then inserted into a two-stage ripple counter, consisting of two J-K flip-flops. The first pulse arriving at the input also triggers a monostable multivibrator which, after a predetermined time (equal to one half of the period of revolution of the vehicle), resets the system. Since the maximum value of T1 is one-third of the revolution period the reset ensures that the start and stop signals are generated in the proper sequence.

The diamond-shaped aperture of the sensor above is ambiguous with respect to the forward and backward directions. A third, central, pulse is added to distinguish the forward direction. A switch in the system allows the stop command to be generated on the second or third pulse, as established by inspection of the pulse train. Also the solar aspect sensor on Nike Cajun 10.320 was modified because of a limited view angle and it was equivalent to a two-pulse system in the forward direction and a four-pulse system in the backward direction. All angles were, however, in the forward direction during this flight.

The time corresponding to each number from the digital printer is established by simultaneously running a chart record, at 1 inch per second, with the solar aspect sensor signal, the start and stop pulses and the 28-bit time code. As an additional check the 100 kHz signal to the printer is periodically interrupted, producing a blank space on the printer and a mark on the chart record.

A plot of the solar aspect angle of Nike Apache 14.392 for the first 300 revolutions following door ejection is shown in Figure 8. The period covered is 32 seconds. The angle plotted is measured from the perpendicular

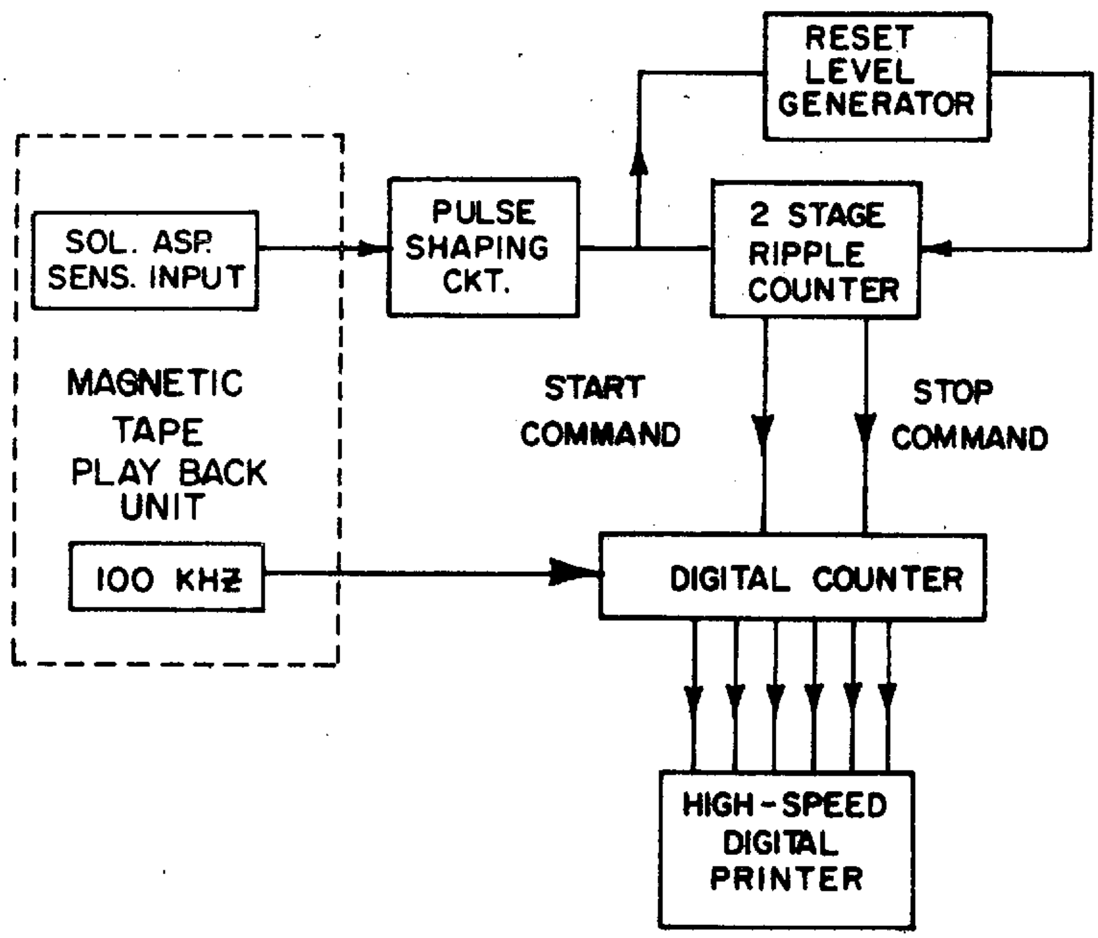


Fig. 7. Solar Aspect Angle Data Reduction Scheme

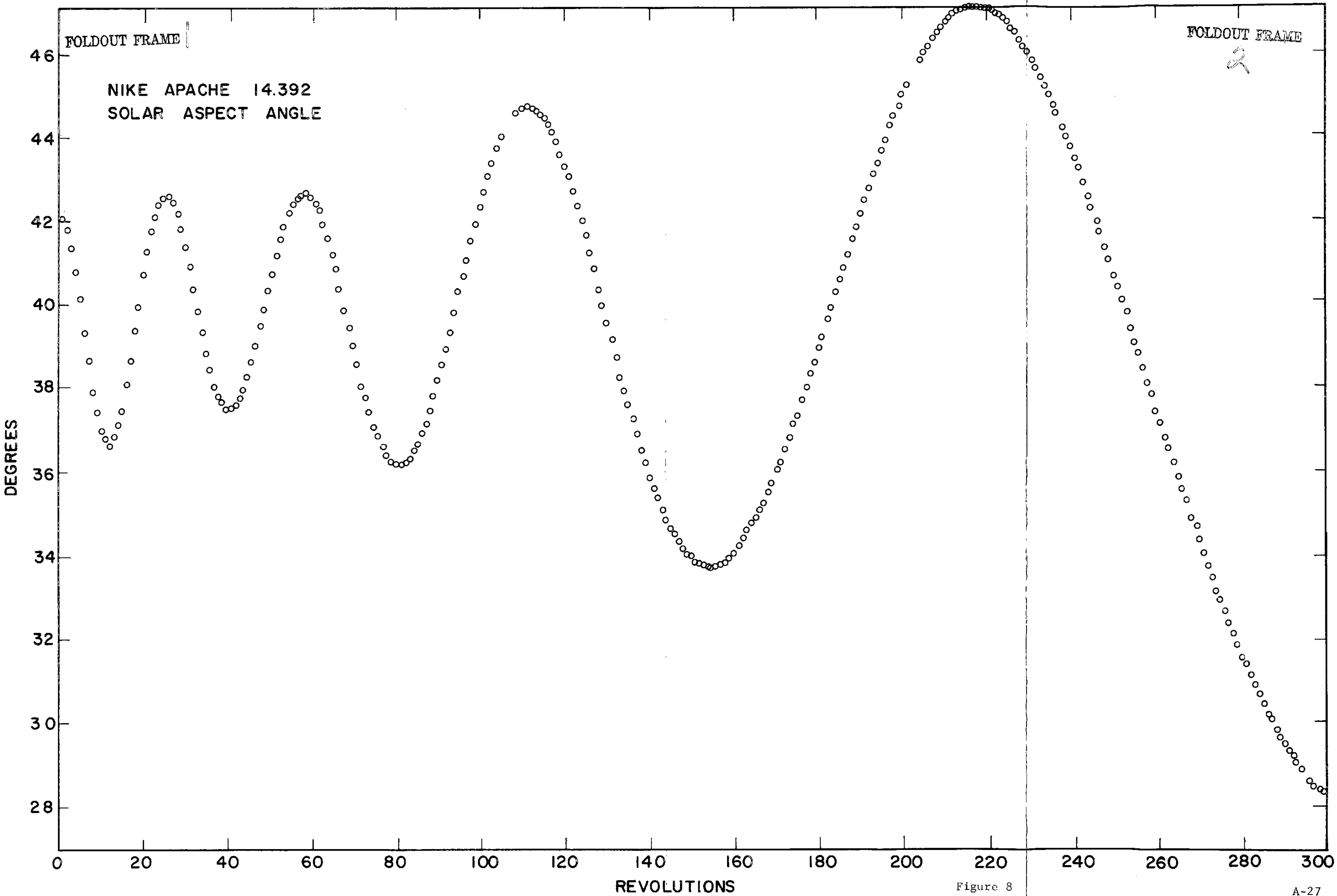

FOLDOUT FRAME
FOLDOUT FRAME
NIKE APACHE 14.392
SOLAR ASPECT ANGLE
DEGREES
46
44
42
40
38
36
34
32
30
28
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
REVOLUTIONS

Figure 8

to the spin axis.

The data from the following flights have been processed by the new method: 14.358/9, 14.391/2, 14.395, 14.435/6/7/8 and 10.320. The more accurate solar aspect angle data will make it possible to extend the ozone concentration profiles to greater altitudes than has been previously possible. The new method has the additional advantage of reducing the time and effort required to measure the aspect data.

APPENDIX B

I. INTRODUCTION

The period reported here includes the successful launch of three rockets in an investigation of the D and E regions at sunrise and the analysis of data resulting from other rocket launches. A listing of the eight rocket launches accomplished on this contract is given in Table 1. Three additional payloads are being prepared for launches in January 1972 in a study of the winter anomaly in electron density in the D region. The field trip and subsequent data analysis are included in a proposed extension of the contract (GCA proposal number 4335-6-01).

The next section of this report concerns data from the eclipse of 7 March 1970. Three papers have been prepared and accepted for publication in Journal of Atmospheric and Terrestial Physics. These are listed in Table 2, which also includes a paper on Sporadic-E accepted for publication in Radio Science. This latter paper is mainly based on data from flights on earlier contracts (NASW-1141 and NASW-1402). The abstracts of these papers are included in the Appendix to this report; pre-prints are available on request.

The third section contains a description of the series of launches on 20 August 1971. A preliminary evaluation of the individual experiments indicates a successful operation.

The final section describes plans for future launches and data analysis.

Table 1: Rocket Launches, Contract NASW-1994

Vehicle*	Time LST	Date	Place**	Remarks***
14.435	1045	7 Mar 1970	W.I.	Pre-eclipse
14.436	1337:10	7 Mar 1970	W.I.	Eclipse
14.437	1338	7 Mar 1970	W.I.	Eclipse
14.438	1340:40	7 Mar 1970	W.I.	Eclipse
10.320	1100	16 Jul 1970	W.I.	Sporadic-E
14.475	0419	20 Aug 1971	W.I.	$\chi=102^{\circ}$
14.476	0444	20 Aug 1971	W.I.	$\chi=97.5^{\circ}$
14.477	0514	20 Aug 1971	W.I.	$\chi=92^{\circ}$

*Prefix 14. =Nike Apache, 10.= Nike Cajun

**W.I. =Wallops Island, Virginia (37.84°N, 75.48°W)

***χ =Solar Zenith angle

Table 2: Paper Prepared on Contract NASW-1994

1. L.G. Smith "Rocket Observations of Solar UV Radiation during the eclipse of 7 March 1970."
2. C.A. Accardo, L.G. Smith and G.A. Pintal, "Rocket Observations of Solar X-Rays during the eclipse of 7 March 1970." *
3. E.A. Mechtly, C.F. Sechrist and L.G. Smith "Electron loss Coifficients for the D-Region of the Ionosphere from Rocket Measurements during the Eclipse of March 1970 and November 1966."**
4. L.G. Smith and E.A. Mechtly "Rocket Observations of Sporadic-E layers."**

*Prepared jointly on contracts NASW-1993 and NASW-1994.
**Prepared jointly on contract NASW-1994 and grant NGR 013 (Aeronomy Laboratory, University of Illinois).

II. ECLIPSE DATA ANALYSIS

No radar trajectory was obtained for Nike Apache 14.437 launched during the eclipse of 7 March 1970. A method of reconstructing a trajectory was indicated in the previous report. This was based on the use of altitude switches (70,000 ft.) in the payload and certain details of fine structure in the ionosphere profile which could also be identified in the data from Nike Apache 14.436, launched 50 seconds earlier than 14.437.

In the course of this analysis it became obvious that the trajectories of 14.436 and 14.438 showed that the altitude of these rockets in the early part of the flight was about 3 km greater than any reasonable variation in performance would permit. This is illustrated in Figure 1 which shows the altitude and total velocity at 20 seconds after launch; no flights are included in which the second stage ignition occurred earlier than T+20 seconds.

Twelve payloads of approximately the same weight and configuration are shown, together with the prediction for the eclipse rockets for two values of the effective launch angle (74.5 deg and 78 deg.). The value for 14.435, 14.436 and 14.438 from the first radar printouts are shown at one end of a line and the final value at the other end, with the arrow pointing toward the final value. Initially there was no reason to question the trajectory of 14.435.

The exceptional behavior of 14.436 and 14.438 was discussed with

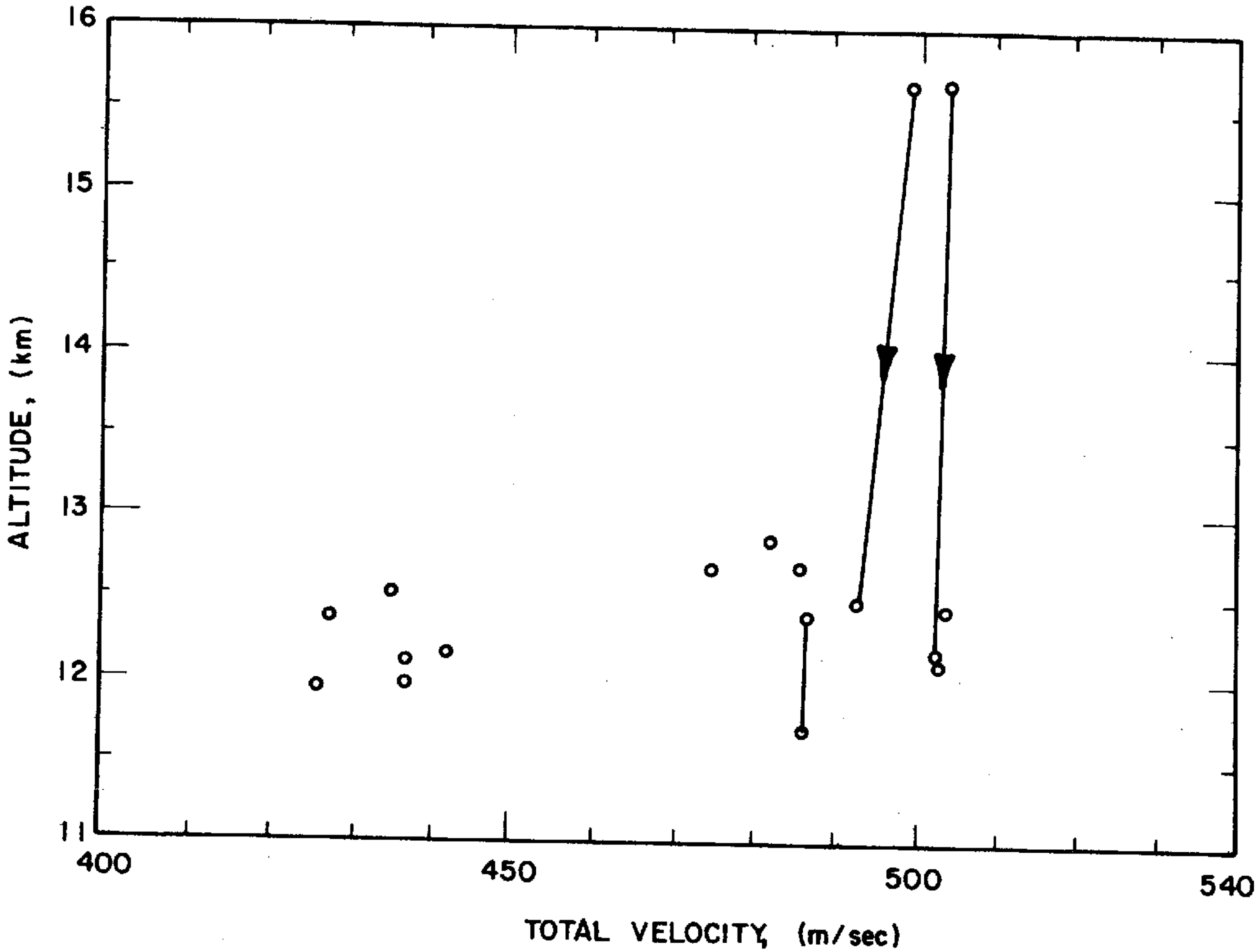


Figure 1. Altitude and total velocity at T + 20 sec.

Wallops Island personnel. The cause of the discrepancy was finally traced to the use of incorrect values of delay for the transponders used with these two flights. At the same time an error of a different type was found in the trajectory of 14.435. The error in transponder delay also applied to many other rockets launched during the eclipse operation.

The eclipse circumstances at the rockets have been re-calculated using the corrected trajectories and are presented (in different ways) in papers 1 and 3 of Table 2. The altitude trajectory of 14.437 is generated by making a slight adjustment to the trajectory of 14.436; the procedure is (a) subtract 0.8 sec from the time-from-launch and (b) subtract 2.20km from the altitude. Since there is no immediate information on horizontal position of 14.437 this was assumed to be the same as for 14.436 at the delayed time. The exit from the shadow for both flights agrees well with the data from the 2600A detector, confirming the correctness of the assumption, at least to the accuracy necessary for analysis of the data from the Lyman-α detector.

The final values of apogee for the four eclipse flights are:

14.435	185.1 km
14.436	172.7 km
14.437	170.5 km
14.438	186.5 km

The analysis of data from the Lyman-α detectors is essentially complete and is being published (papers 1 of Table 2). The most important finding is that there is a substantial flux of Lyman-α

in totality. This is, in part, of coronal origin but in addition there is a source near the horizon which is important above 80 km. Below that altitude the flux from the horizon is rapidly attenuated. It is shown in the paper that at 80 km the flux of Lyman-α in totality is not negligible if the loss process for electrons is a recombination; it is negligible if the loss process is attachment-like. The nature of the loss process remains one of the most critical unresolved questions of D-region aeronomy.

The analysis of data from the 2600A detector is continuing. Two main points are being investigated. The first is the predicted increase in ozone during the eclipse which is measured from the absorption profile of 2600A. Preliminary indication is that in the altitude range 60 to 68 km an increase of about a factor of two occurred. At lower altitudes, as predicted, no increase is found. The other interesting aspect of these data is the limb brightness of the sun at this wavelength. It is apparent that there is darkening at the limb but the variation of brightness with solar radius has not yet been determined. This analysis is continuing.

III. SUNRISE LAUNCHES

The observation of the C and D layers at sunrise is a powerful method of investigating the sources of ionization and the process by which electrons are lost. In addition the initial ionization in the E region at sunrise can be used to determine the concentration of nitric oxide.*

*L.G. Smith, "Ionization by Lyman-α in the E-Region at Sunrise," J. Atmos. Terr. Phys. 28, 1195-1205, 1966.

Launch times for the three rockets flown in this operation were calculated for solar zenith angles of 102 deg, 97.5 deg and 92 deg. The geometrical shadow height (i.e. the altitude at which the sun appears at the horizon) for each of the flights is 144, 56 and 4km, respectively, at launch time. The particular angles were selected so that the first and second launches would be used in an investigation of the initial ionization of the upper E region by Lyman-α extending the determination of nitric oxide concentration to an altitude of about 170km. The launch time of the third rocket was selected primarily to observe an intermediate stage in the development of the C layer.

Nine rockets carrying related experiments were launched in this operation during a 16-hour period on 19 and 20 August 1971. These are shown in Table 3. The Robin Sphere experiment is an atmospheric density measurement derived from observation of fall velocity of an inflated sphere. The atomic oxygen measurement is an experiment of W. Henderson, NOAA, based on the change of resistivity of a silver film as it is oxydized. The Pitot-Probe experiment of J. Horvath University of Michigan, gives atmospheric density. These complement the molecular oxygen and ozone experiments in the ionosphere payloads.

Two types of payloads were used for the ionosphere experiments. The first two flown on Nike Apache 14.475 and 14.476, were Type B Mod. 4 payloads with the following group of experiments:

1. CW propagation experiment; the frequencies used were 2.225 and

Table 3: Sunrise Launch Series, August 1971

Vehicle*	Date	EST	Experiment
Viper Dart	19	1332	Robin Sphere
10.389	19	1456	Atomic Oxygen
14.491	19	1511	Pitot Probe
10.390	20	0230	Atomic Oxygen
14.492	20	0245	Pitot Probe
Viper Dart	20	0302	Robin Sphere
14.475	20	0419	Ionosphere
14.476	20	0444	Ionosphere
14.477	20	0514	Ionosphere

*10. =Nike Cajun

14. =Nike Apache

3.385 MHz on 14.476;

2. DC/Langumiur probe, using the nose-tip electrode; the probe was held in the fixed voltage mode to an altitude of about 120 km;
3. Langumiur probe using boom-mounted electrodes; the sweep duration was 0.5 sec. A magnetic aspect sensor is included in these payloads, primarily in support of the propagation experiments.

The third payload, flown on Nike Apache 14.477, was Type A Mod. 7 with the following experiments:

1. CW propagation experiment; the frequencies used were 2.225 and 3.385 MHz.
2. DC/Langumiur probe, using the nose-tip electrode; this alternated 0.3 sec. sweep mode and 1.7 sec. fixed-voltage made throughout the flight.
3. Solar UV radiation detectors at Lyman-α (1216A) and at 2600A. These are used primarily to obtain the absorption profiles at the two wavelengths which lead to concentration of molecules oxygen and ozone, respectively.

A magnetic and solar aspect sensor are included in support of these experiments.

The telemetry assignments of the three payloads are given in Table 4.

The launches were first scheduled for the morning of 18 August, 1971, a Quarterly World Day, but predictions of unfavorable weather forced postponement for two days. The first launch, Nike Apache 14.475, was made at 0419 EST on 20 August 1971, with Nike Apache 14.476 launched 25 minutes later, at 0444 EST and Nike Apache 14.477, launched at 0514 EST,

Table 4: Telemetry Channel Assignments, Sunrise Series

Channel	14.475/6	14.477
19	Boom probe, log	Solar aspect
18	Receiver #1 (2225 KHz), modulation	Receiver #1 (2225 kHz), modulation
17	Receiver #2 (*), modulation	Receiver #2 (3385 kHz), modulation
16	Tip probe, log	Probe, log
15	Tip probe, linear	Probe, linear
14	Boom probe, linear	UV, high gain
13	Magnetic aspect	Magnetic aspect and release monitor
12	Release monitor	UV, low gain
11	Receiver #1, AGC	Receiver #1, AGC
10	Receiver #2, AGC	Receiver #2, AGC

*7.9225 MHz in 14.475; 3385 KHz in 14.476

Table 5: Events Determined From Telemetry Records

Event (UT)	14.475	14.476	14.477
Launch Time	0919:00	0944:00	1014:00
Second Stage Ignition	0919:21.5	0944:20.1	1014:21.4
40 kft Baroswitch on	0919:20.3	0944:20.0	1014:21.2
70 kft Baroswitch on	0919:28.0	0944:27.0	1014:28.2
Door ejection	0919:28.0	0944:52.3	1014:38.8
Boom deployment	0919:54.2	0944:52.8	*
70 kft Baroswitch off	Not observed	0950:59.0	1021:03.8
40 kft Baroswitch off	Not observed	Not observed	1021:08.1
Loss of Signal	0925:55.3	0950:59.7	1021:19.7

*This payload did not include booms.

55 minutes after the first launch. The times of second stage ignition and other events in the flights, obtained from the telemetry records, are given in Table 5.

On both 14.475 and 14.476 the telemetry signal ceased near the end of the flight with the rockets at an altitude of 70,000 ft. No data were lost but the unexpected behavior is disturbing and is being investigated; the cause is not immediately obvious. An apparently identical loss of the telemetry signal near the end of the flight at 70,000 ft. also occurred on Nike Apache 14.394, launched on 12 September 1969; this vehicle also carried a Type B payload.

Further details of vehicle performance are given in Table 6. The spin rate of Nike Apache 14.476 immediately prior to boom deployment was observed to be 7.2 rps compared with a desired value of 6 rps. The experiment using the booms appears to have been successful but the unusually large half-angle of the precesion cone can be interpreted as an indication of the failure of one of the booms. The electrodes at the ends of the booms are connected together to the input of the experiment and the loss of one boom would not be of consequence since the effect would be to reduce by a factor of two the exposed area of electrode.

Preliminary inspection of the data from the three flights indicates a completely successful operation. Data analysis for this series has been started.

Table 6: Vehicle Performance

	14.475	14.476	14.477
Apogee, km	193.3	198.0	200.4
Apogee, UT	0922:41	0947:42.5	1017:45.0
Flight azimuth*, deg	107.2	108.8	111.2
Spin rate, rps	6.6/4.9**	7.2/5.3*	5.4*
Precession Cone: Period*, sec	34.7	32.2	39.7
Precession Cone: Half-angle*, deg	17.5	27.8	18.0

*Measured at apogee

*Before/after boom deployment

IV. FUTURE PLANS

The work remaining to be performed on this contract consists of the following items:

1. Completion of the fabrication of three payloads;
2. Calibration, checkout and testing of these payloads;
3. Data analysis for the three rockets launched from Wallops Island on 20 August 1971; and
4. Preparation of a final report.

The present completion date is 31 December 1971. However, the environmental testing of three payloads, part of item 2 above, has been delayed to the period 3-13 January 1972, because of circumstances beyond our control. The field trip for the launch of these three rockets is scheduled to start on 14 January 1972. This is one item in the extension of the contract, described in GCA proposal numbers 4335-6-01. These launches are part of a cooperative effort involving scientists from the University of Illionis, York University, Pennsylvania State University and Air Force Cambridge Research Laboratories.

The proposal for the continuation of the investigation of the D and E regions of the ionosphere also recommends a coordinated program of rocket and ground-based observations of sporadic-E layers. Two Type B payloads, including boom-mounted probes for electron temperature measurement, and a radio propagation experiment, modified to investigate the horizontal variation in the structure of the layer, would be flown on Nike Apache rockets. Other experiments with rocket-borne and ground-based experiments would be encouraged to coordinate their operation with both series of rocket launches. The investigation would be scheduled for July 1972 at Wallops Island.

APPENDIX C

I. SUNRISE SERIES

Three rockets were launched from Wallops Island on 20 August 1971 in an investigation of the D and E regions at sunrise. Some details of vehicle performance have already been reported. The flights were entirely successful with respect to the scientific objectives of the series.

The times of the launches and the solar zenith angle at the rocket at an altitude of 90 km, both for ascent and descent, are as follows:

Nike Apache	14.475	0919 UT	101.8°	100.1°
Nike Apache	14.476	0944 UT	97.4°	95.8°
Nike Apache	14.477	1014 UT	91.8°	89.9°

The minimum ray height and related quantities used in the analysis of the Lyman-α and 2600Å absorption profiles have been calculated for Nike Apache 14.477, which carried UV sensors.

This was geomagnetically a very quiet day and has subsequently been selected by IAGA Commission IV as one of the five quiet days of August, 1971. The Kp indices for the three-hour intervals on 20 August 1971 are:

Universal Time:	0 - 3	3 - 6	6 - 9	9 - 12	12 - 15	15 - 18	18 - 21	21 - 24
Kp index:	0+	1o	0+	0o	0+	2-	1+	2o

The profiles of probe current from each of the flights have been obtained. Pending a final calibration obtained from the propagation experiment the electron density (cm^{-3}) may be estimated by multiplying the current (amp) by 10^{10}.

The first flight was made at a time when none of the ionizing radiations from the sun were illuminating the region. With the rocket at 90 km altitude on ascent the geometrical shadow height is 137 km. This profile thus represents the structure prior to layer sunrise.

The sharp lower boundary characteristic of the nighttime ionosphere may be noted. The region between 90 and 120 km shows a relatively irregular structure with the (provisional) electron density values ranging from a minimum of $2 \times 10^3 cm^{-3}$ to a maximum, in the sporadic-E layer, of about $1.4 \times 10^4 cm^{-3}$. The altitude at the peak of this sporadic-E layer is determined to be 118.68 km on the ascent profile and 116.74 km on the descent profile (not shown). The horizontal separation of the two penetrations is 101.5 km, indicating a slope of -1.09 degree. The flight azimuth is 107 degree, east of north.

Above the sporadic-E layer the electron density is smooth, decreasing to a minimum of 400 cm^{-3} (provisional) at an altitude of 143 km before increasing monotonically to rocket apogee (193.3 km).

The next profile, shown in Figure 2, has similar features to that observed 25 minutes previously, but changes can be clearly seen. Some of these are attributed to effect of illumination by solar radiation, while others illustrate the redistribution of ionization caused by the neutral wind.

The relatively steep lower boundary of the ionosphere is again seen though its structure differs in detail from that of the preceding profile The irregular region from 90 to 120 km is similar to that of the preceding profile with the electron density values (provisional) ranging from a minimum of $2.3 \times 10^3 cm^{-3}$ to a maximum, in the sporadic-E layer of $1.5 \times 10^4 cm^{-3}$. The sporadic-E layer appears several kilometers lower than the preceding profile; on ascent the altitude of the peak is 114.60 km and on descent it is 113.83 km. The horizontal separation of these penetrations is 86.8 km giving a value for the slope of -0.51 degree. The flight azimuth is 109 degree, east of north.

The descent of the sporadic-E layer is interpreted as an effect of the neutral (horizontal) winds. The gradual descent of a sporadic-E layer from a altitude of about 150 km at midnight to about 120 km at sunrise is believed to be a regular feature of the nighttime E region.*

The upper part of this profile shows a minimum electron density (provisional) of $1.1 \times 10^3 cm^{-3}$ at 135 km with a monotonic increase to rocket apogee (198.0 km). Comparison with the corresponding part of the previous profile shows an increase in electron density at all altitudes above 128 km. This is the initial development of the E-region resulting

*L. G. Smith, "A sequence of rocket observations of nighttime sporadic-E," J. Atmos. Terr. Phys. 32, 1247-1257 (1970).

from ionization of nitric oxide by (direct) solar Lyman-α radiation.* Examining the region immediately above the sporadic-E layers indicates that the enhancement is detectable down to an altitude of 122 km. The geometrical shadow height at the time that the rocket was at 90 km altitude on ascent is 52 km.

The final profile of the series was obtained 30 minutes after that just described. The geometrical shadow height with the rocket at 90 km on ascent is 3 km. The profile, shown in Figure 3, is markedly different from the two preceding. The C-layer, seen between 60 and 83 km is now present and the E-region above 100 km is well developed. Only in the region from about 83 to 97 km is the electron density not substantially increased over that observed at the earlier times. The peak of the sporadic-E layer is seen on the ascent profile, at about 113 km. The apogee of this vehicle was 200.4 km.

Data reduction to obtain the flux of Lyman-α and the concentration profiles of O_2 and O_3 has been started. These will be used in the analysis of the electron density profiles.

The other major part of the data reduction is the measurement of electron temperature in the E-region. This is obtained from the nose-tip Langmuir probe and also, in the case of the first two rockets in the

---

*L. G. Smith, "Ionization by Lyman-α in the E-region at Sunrise," J. Atmos. Terr. Phys. 28, 1195-1205 (1966).

series, from boom-mounted Langmuir probes. The inter-comparison of the two measurements on each of these two rockets is of particular importance in view of the discrepancies that have been reported between rocket (and satellite)-borne probes and incoherent scatter observations.

II. WINTER ANOMALY SERIES

The period reported here has been mainly occupied by the preparation of three payloads in anticipation of the Winter Anomaly Series of rocket launches planned for January and February 1972 at Wallops Island. At the end of the period the payloads are complete, with the exception noted below, and are to be taken to Wallops Island for testing. This will occupy the first two weeks of January 1972. The field trip for the launches and subsequent data analysis are included in a proposed extension of the contract (GCA proposal number 4335-6-01).

Two of the three payloads are for Nike Apache rockets (14.439 and 14.440); the other is for a Nike Cajun rocket (10.407). The two Nike Apache payloads are essentially the Type A Mod. 7 developed for the eclipse operation of 7 March 1970 (Nike Apaches 14.435/6/7/8). The complement of experiments in each Nike Apache payload consists of the following:

1. Two CW propagation experiments, using frequencies of 2225 kHz and 5040 kHz; giving electron density and electron collision frequency.

2. DC/Langmuir probe, using the nose-tip electrode, with the sweep mode suppressed to an altitude of 120 km on ascent; giving a high-resolution profile of probe current (electron density) and E-region electron temperature.

3. Solar UV detectors at Lyman-α (1216Å) and at 2600Å; giving the density profiles of O_2 and O_3, respectively, by absorption spectroscopy.

4. Geiger counter sensitive to solar X-rays (2-8Å) and to electrons with energies greater than 70 keV; both of which are potential sources of ionization in the D-region.

In addition, each payload includes a solar and a magnetic aspect sensor. The FM/FM telemetry system uses IRIG Channels 10 to 20 with the signals assigned as shown in Table 1.

The Geiger counters used in these two payloads have windows of 0.2 in diameter (area 0.203 cm^2) fabricated from beryllium of 2 mil thickness (5.1×10^{-3} cm). This window passes X-rays in the wavelength range 2 to 8Å, and, additionally, electrons with energies greater than 70 keV. (it is also sensitive to protons with energies greater than 2 Mev, but this is not relevant to the present flights). The body of the Geiger counter (steel, thickness 0.02 inch) allows cosmic rays to be detected; these define the detection sensitivity for the energetic electrons.

The signals (i.e. counts) from the X-rays and from the corpuscular radiation are distinguished in the experiment on the basis of their directional properties. The X-rays are observed only in the direction of the sun whereas the particles are not so limited and should be essentially uniform in azimuth as the rocket spins. A plate having a longitudinal slot 0.5 inch wide and 3.4 inch long is placed in front of the Geiger counter. The position is such that the counter will be illuminated by the sun for a portion of the rotation of the rocket (nominally 60 deg out of 360 deg). For the remainder of each revolution the counter will be shielded from the X-rays but able to accept the energetic electrons over a solid angle of about one steradian. (The exact value will be determined by the final configuration). In this way it will be possible to measure the flux both of 2-8Å X-rays and greater than 70 keV electrons. The computed ionization production rate of these two radiations will be compared with the production rate resulting from ionization of nitric oxide by Lyman-α radiation.

The third payload, to be flown on Nike Cajun 10.407, differs from the two described above in that it includes an experiment to measure the concentration of atomic oxygen in the D-region; the range is about 10^{10} to $10^{12}cm^{-3}$. The experiment has been developed by R. A. Young and A. Deans at the Center for Research in Experimental Space Science at York University. The experiment will not be described in detail here. In essence it consists in illuminating the ambient atomic oxygen by a UV light source in the payload and measuring the radiation scattered at 1306Å, using detectors also included in the payload. In order to accomodate this experiment in a Type A payload the solar UV experiment and the X-ray/electron experiments have been removed and replaced by the detector assembly. The light source has been included by extending the adapter section of the payload, increasing the overall length by 4.38 inch to 77.94 inch. In addition, because one element of the turnstyle antenna blocked the beam from the light source, this payload has a two-element antenna (i.e. dipole).

This re-designed payload has been designated Type A Mod. 8. The channel assignments of the FM/FM telemetry system are given in Table 2.

One of the requirements of the atomic oxygen experiment is that the velocity of the payload be kept to a minimum (because of Doppler shift of the wavelength used). Accordingly, the flight, originally planned for a Nike Apache vehicle, has been changed to a Nike Cajun. Additional weight will be carried in order to limit the apogee to about 120 km.

III. FUTURE PLANS

The work remaining to be performed on this contract consists of the following items:

1. Checkout and testing of the three payloads of the Winter Anomaly Series; to be performed at Wallops Island between 5 and 14 January 1972;

2. Completion of data reduction and analysis for the sunrise series of 20 August 1971;

3. Preparation of a final report.

The original completion date was 31 December 1971. An extension in time, without additional finds, to 29 February 1972 has been requested.

As previously reported, a proposal for continuation of this investigation has been submitted (GCA proposal number 4335-6-01).

TABLE 1

TELEMETRY CHANNEL ASSIGNMENTS, WINTER ANOMALY SERIES

Channel	Type A Mod. 7
20	Geiger counter
19	Solar aspect
18	Receiver #1 (2225 KHz), mod.
17	Receiver #2 (5040 KHz), mod.
16	Probe, log.
15	Probe, lin.
14	UV, high gain
13	Magnetic aspect and release monitor
12	UV, low gain
11	Receiver #1, AGC
10	Receiver #2, AGC

TABLE 2

TELEMETRY CHANNEL ASSIGNMENTS, WINTER ANOMALY SERIES

Channel	Type A. Mod. 8
20	Detector #3
19	Solar aspect and release monitor
18	Receiver #1 (2225 kHz) mod.
17	Receiver #2 (5040 kHz) mod.
16	Probe, log.
15	Detector #2
14	Detector #1
13	Magnetic aspect
12	Lamp modulation
11	Receiver #1, AGC
10	Commutator*

*Commutated signals: (1) Detector range indicator
(2) Lamp intensity monitor
(3) Lamp temperature monitor
(4) Sync pulse

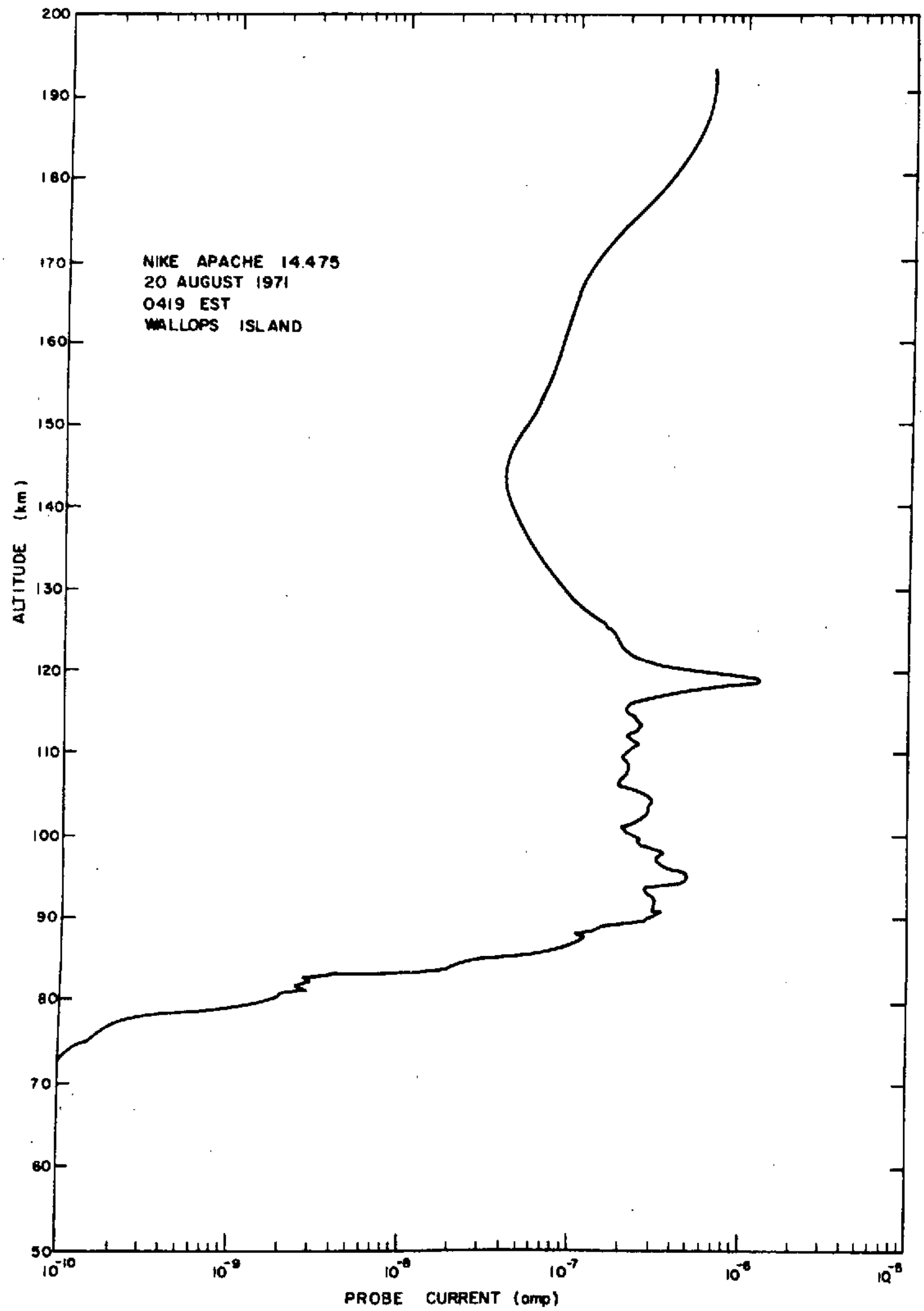


Figure 1. Probe current profile from Nike Apache 14.475

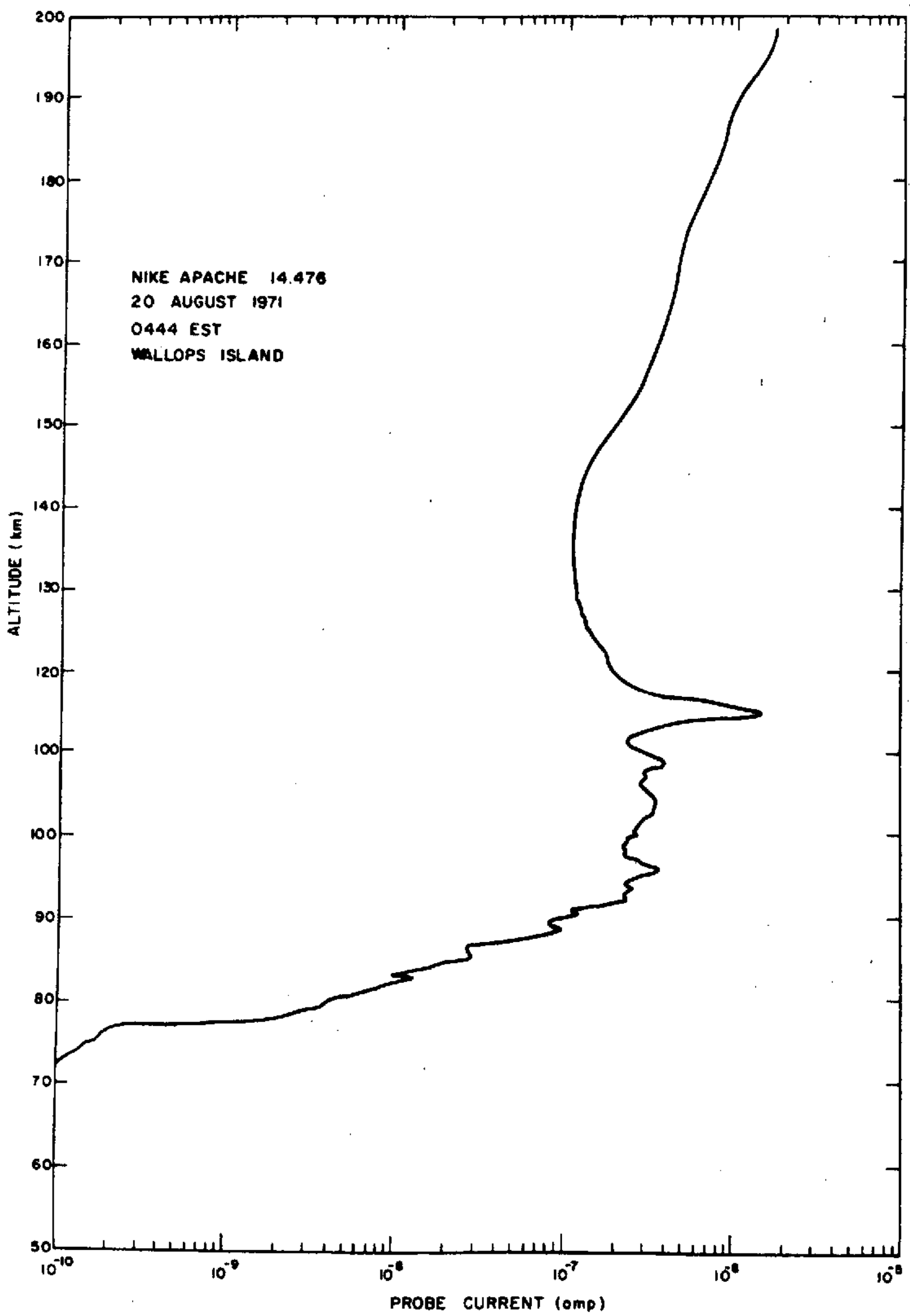


Figure 2. Probe current profile from Nike Apache 14.476

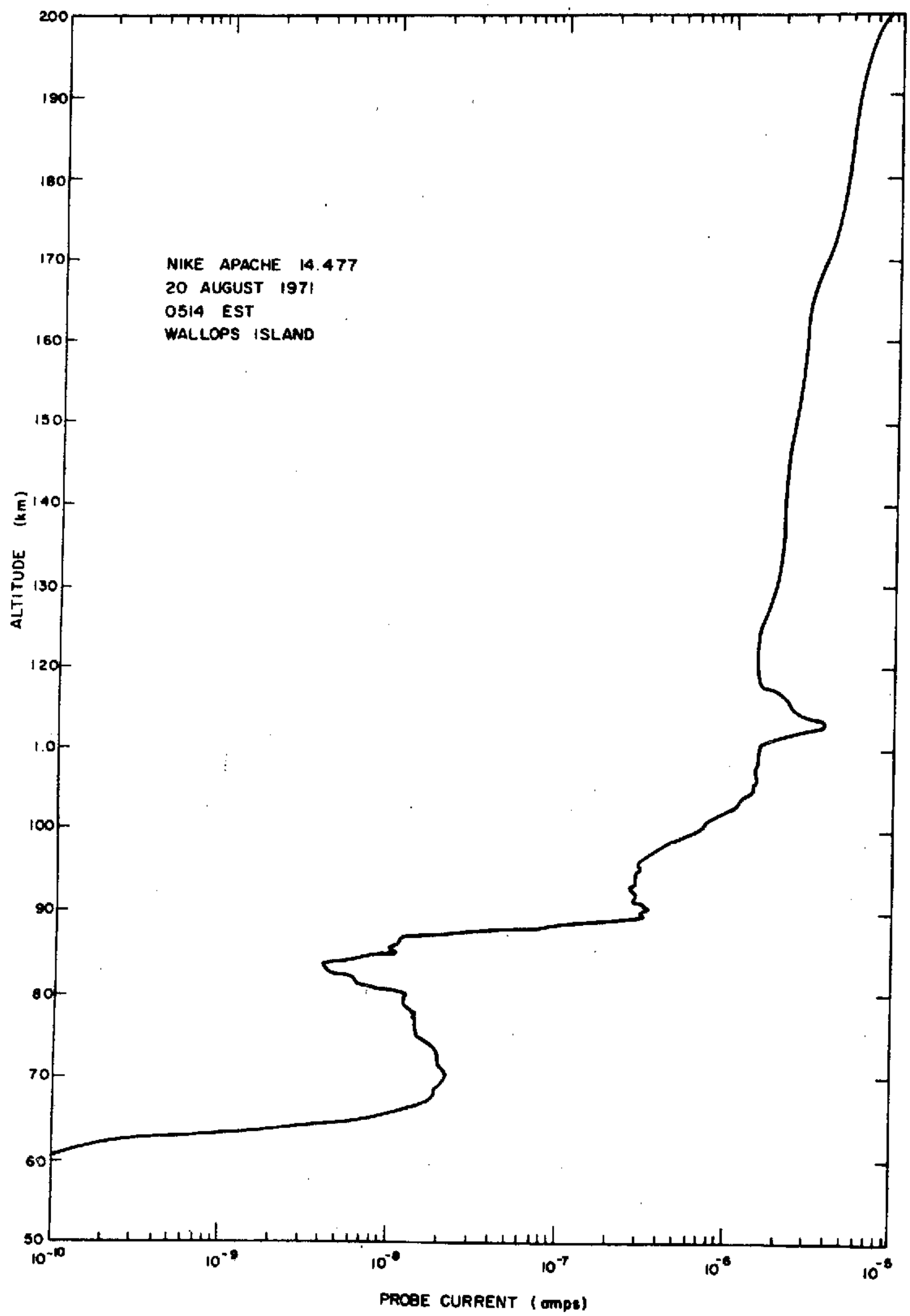


Figure 3. Probe current profile from Nike Apache 14.477

APPENDIX D

I. INTRODUCTION

The effort during this reporting period has been divided between data reduction and preparations for forthcoming flights. Data from the flight of Nike Apache 14.440 were presented at a meeting on the Winter Anomaly Program, held in Chicago on 13 July 1972. These are described further in the next section of this report.

Plans for the launch of Nike Apache 14.439 are now definite. As noted in section III, because of the special geophysical conditions required at the time of launch, a method of operation is being tried which will minimize the time that personnel from GCA Technology Division and the University of Illinois are required to wait at Wallops Island.

Construction of the five payloads for Nike Apache rockets has continued. Three of these are now assigned to a continuation of the Winter Anomaly operation at Wallops Island in November and December 1972 and the other two to an investigation of sporadic E at Wallops Island, no earlier than August 1973. One payload, built for Nike Cajun 10.407, is not yet assigned to any specific investigation.

II. WINTER ANOMALY SERIES

Preliminary results of the Winter Anomaly coordinated program of January and February 1972 were presented and discussed at a meeting in Chicago on 13 July 1972.

Nike Apache 14.440 was launched at 1230 EST on 31 January 1972 at Wallops Island. It reached an apogee of 199.5 km. The solar zenith angle at the rocket at an altitude of 90 km is 55.40 deg on ascent and 55.18 deg on descent.

The payload contained the following instrumentation:

1. Nose tip probe operating in the fixed-voltage mode to an altitude of 120 km on ascent and alternating the fixed-and swept-voltage modes for the remainder of the flight. This experiment gives the electron density fine structure and E-region electron temperature.

2. CW propagation experiments using differential absorption, Faraday rotation and standing wave analysis at 2225 and 5040 kHz. This gives electron density and, in the D region, electron collision frequency.

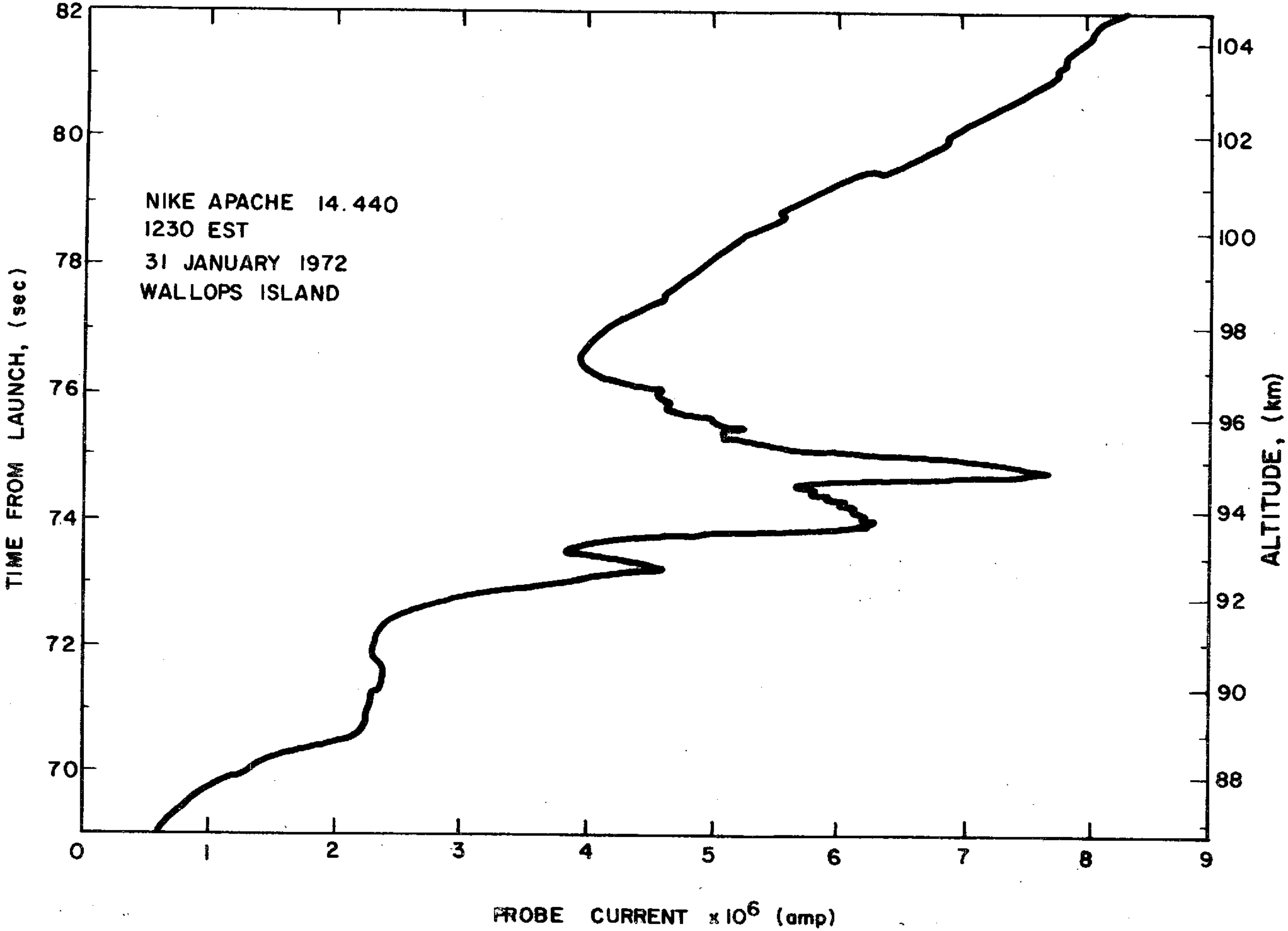
3. Geiger counter with 2 mil Beryllium window. This detector is sensitive to solar X-rays in the wavelength range 1-8A and also electron with energies >70 keV. The two are separated on the basis of direction of arrival.

4. Solar UV experiment consisting of detectors for Lyman-α and on the concentration profiles of O_2 (between 68 and 95 km) and of O_3 (between 45 and 65 km).

5. Solar and magnetic aspect sensors; supporting the UV and propagation experiments, respectively.

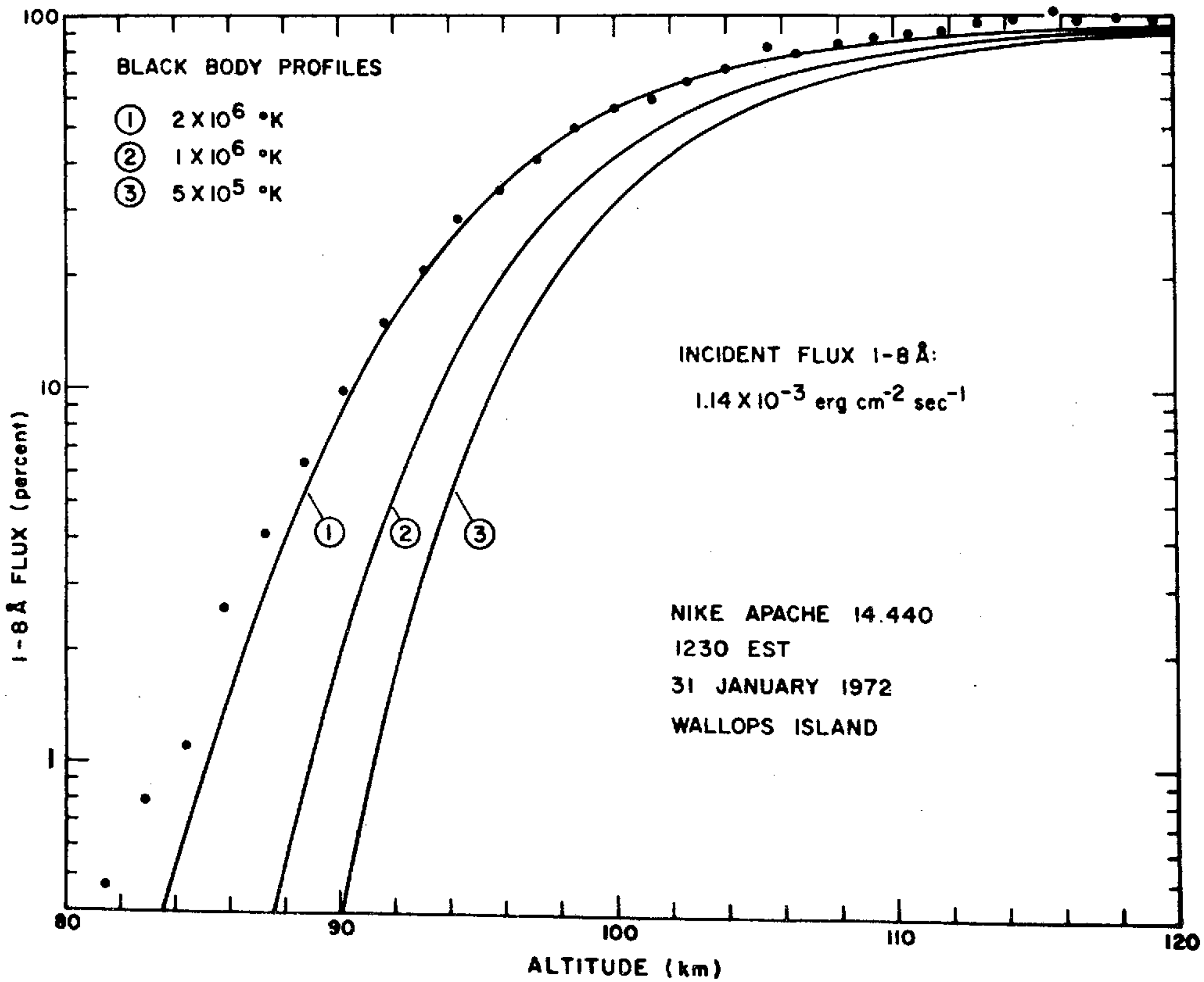
It was noted in the previous report that the electron density profile obtained from the nose-tip probe shows the presence of two sporadic-E layers, an occurrence observed on only one other daytime flight. In both cases the lower layer is at an altitude of about 95 km and the upper at about 112 km. The detailed profile of both layers in the recent profile have been obtained by computer analysis at intervals of 0.01 sec, representing a height resolution of 14 m. The lower layer, shown in Figure 1 as a profile of probe current, shows relatively complex structure. The data from the propagation experiments will be used to determine the ratio of electron density to current for the probe, providing a calibration for this observation.

The absorption profile of solar X-rays in the band 1-8A observed during this flight is shown in Figure 2. Three theoretical absorption profiles for energy distributions represented by black body radiation of $2x10^6$, $1x10^6$ and $5x10^5$ ^oK are also shown. The observed profile can be closely represented by the black body profile for $2x10^6$ ^oK, in agreement with previous observations. It may be noted that for radiation in this part of the spectrum, unit optical depth, where the maximum rate of absorption occurs, is at 94 km. The incident flux is observed to be 1.14×10^{-3} erg cm^{-2} sec^{-1}, in good agreement with the simultaneous value from the SOLRAD satellites.



NIKE APACHE 14.440
1230 EST
31 JANUARY 1972
WALLOPS ISLAND
TIME FROM LAUNCH, (sec)
82
80
78
76
74
72
70
ALTITUDE, (km)
104
102
100
98
96
94
92
90
88
0
1
2
3
4
5
6
7
8
9
PROBE CURRENT x10^6 (amp)

Figure 1.



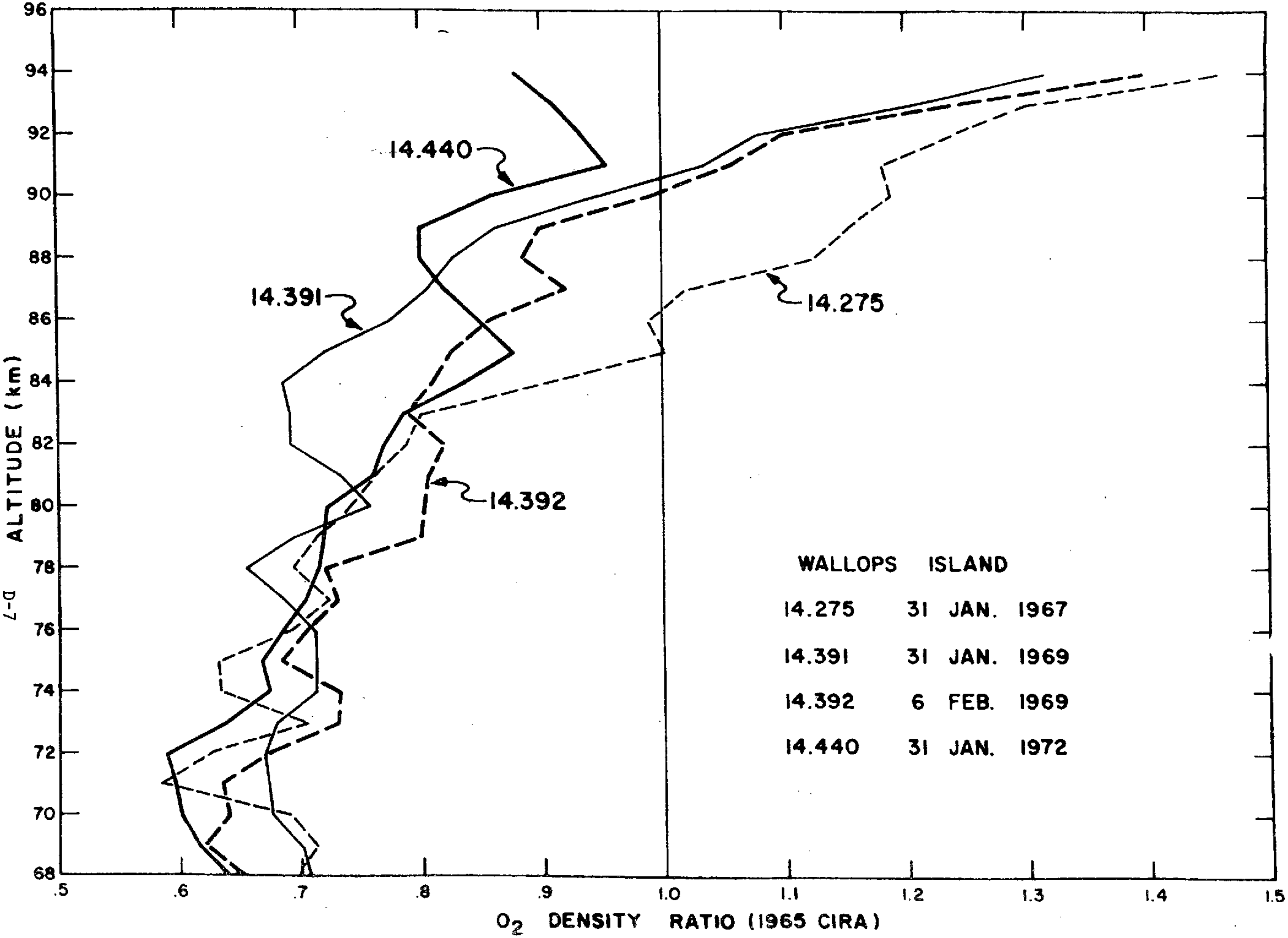
BLACK BODY PROFILES
① 2 X 10^6 °K
② 1 X 10^6 °K
③ 5 X 10^5 °K
INCIDENT FLUX 1-8 Å:
1.14 X 10^-3 erg cm^-2 sec^-1
NIKE APACHE 14.440
1230 EST
31 JANUARY 1972
WALLOPS ISLAND
1-8 Å FLUX (percent)
ALTITUDE (km)
100
10
1
80
90
100
110
120

Figure 2.

The incident flux at Lyman-α is determined to be 2.73 erg cm^{-2} sec^{-1} (1.68×10^{11} photons cm^{-2} sec^{-1}). This is rather lower than the relatively constant value of about 5 erg cm^{-2} sec^{-1} observed (but not simultaneously) by satellite-borne photometers. The calibration procedure of the ion chambers must be re-examined. The concentration profile for molecular oxygen obtained from the absorption profile of Lyman-α is shown in Figure 3 in the form of the ratio to values from 1965 CIRA. Data for three other winter flights are shown. The graphs are drawn by connecting points plotted at 1 km intervals in altitude. The data for 14.440 show an unexpected discrepancy in the density ratio above 91 km. This does not appear in data obtained, nearly simultaneously, using the falling sphere technique by Murphy and Faire (AFCRL).

The concentration profile for ozone, measured on 14.440, is compared in Figure 4 with data from two other winter flights. The data on 14.392 is limited to an altitude of 61 km by poor rocket aspect. There is agreement between the flights to about 56 km but at greater altitudes that from 14.440 is noticeably lower in magnitude compared with the other two flights.

The plans for further coordinated programs were considered at the meeting. Probably the most important factor is that of geographic latitude of the observations. It was reported that, in the Northern hemisphere, the southern limit of the phenomenon has been determined to be between 35 and 40 deg, based on observations from a ship in the North Atlantic Ocean. This means that Wallops Island (38°N) is poorly located



96
94
92
90
88
86
84
82
80
78
76
74
72
70
68
ALTITUDE (km)
.5
.6
.7
.8
.9
1.0
1.1
1.2
1.3
1.4
1.5
O2 DENSITY RATIO (1965 CIRA)
14.440
14.391
14.275
14.392
WALLOPS ISLAND
14.275 31 JAN. 1967
14.391 31 JAN. 1969
14.392 6 FEB. 1969
14.440 31 JAN. 1972

Figure 3.

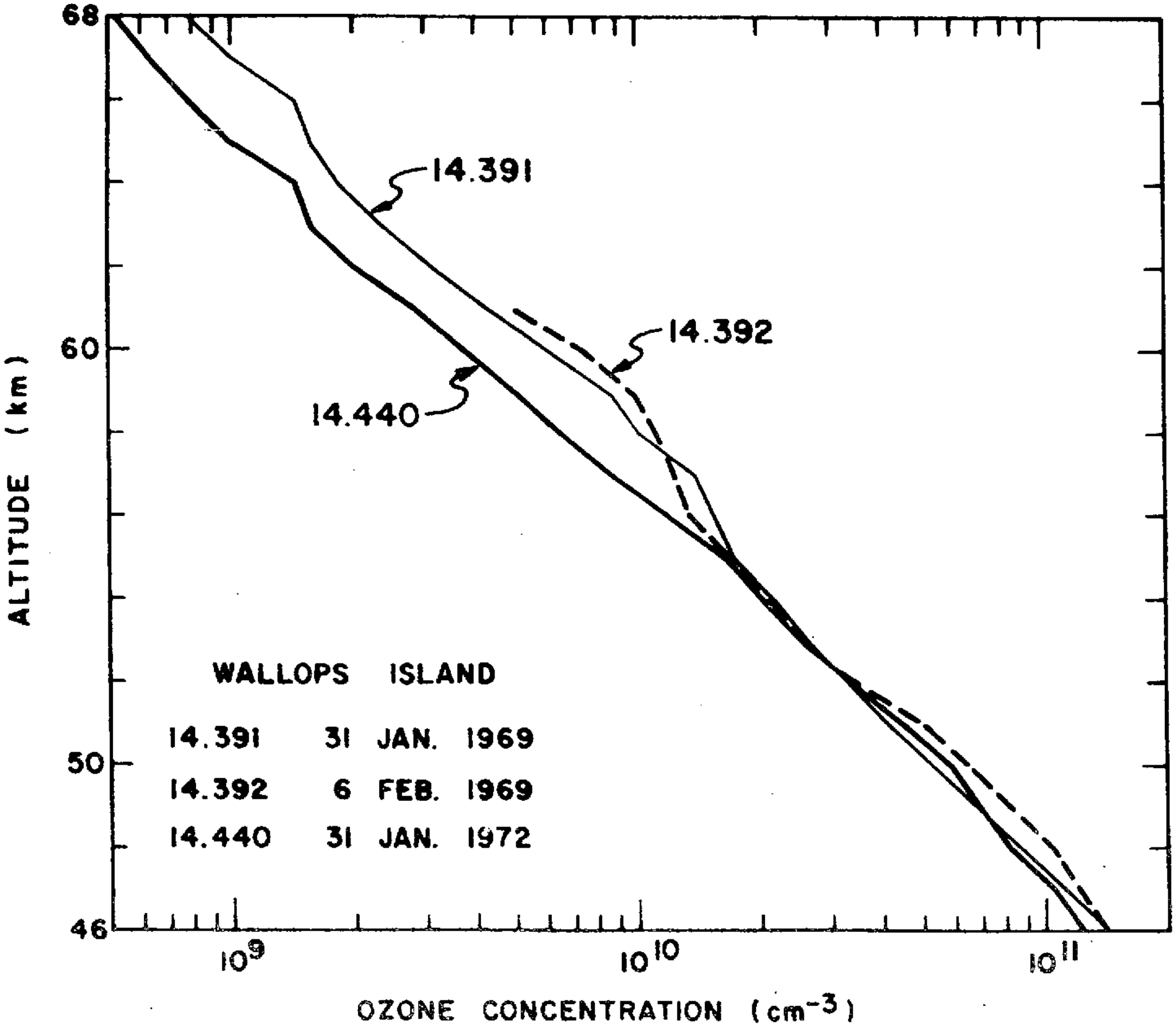

68
60
50
46
ALTITUDE (km)
14.391
14.392
14.440
WALLOPS ISLAND
14.391 31 JAN. 1969
14.392 6 FEB. 1969
14.440 31 JAN. 1972
10^9
10^{10}
10^{11}
OZONE CONCENTRATION (cm^{-3})

Figure 4.

for such studies. As has been observed, there are relatively few days of anomalously high absorption in winter. This may be compared with the situation in Western Europe where observations in England and Germany shown the phenomenon to be present on most winter days. It is to be hoped that a program of rocket measurements combined with ground observations can be arranged in Western Europe.

III. NIKE APACHE 14.439

The electron density profile of the E region near midnight at Wallops Island is characterized by a layer at about 150 km separated from a lower irregular region by a deep valley.* This structure develops by vertical redistribution of ionization resulting from shears in the neutral (horizontal) wind. The electron density minimum is about 150 cm^{-3} at an altitude of 120 km on the four separate nights for which rocket observations are available.

The magnitude of the electron density in the valley is influenced by the rate of ionization in the region and the observations are consistant with a small flux of scattered solar UV radiation. Observations at Fort Churchill, on the other hand, show no valley at midnight and the relatively high electron density throughout the upper E region (10^4 to 10^5 cm^{-3}) is consistant with an influx of energetic electrons, which also produce visual auroras. One of the major unsolved problems of the mid-latitude ionosphere is the question of the importance of energetic electrons as a source of ionization. Auroral displays are rare occurrences at Wallops Island but it is possible for electron fluxes to be important at night, as a source of ionization, without their presence being detected photometrically. The scientific objective of the flight of Nike Apache 14.439 is to determine whether there is any evidence of energetic electrons as an important source of ionization at night in mid-latitudes. This will

---

*L. G. Smith, "A sequence of rocket observations of night time sporadic-E" J. Atmos. Terr. Phys. 32, 1247-1257, 1970 be accomplished by observing the electron density profile near midnight and by a direct measurement of the flux of electrons with energies >70 keV.

The previous observations of the electron density profile at midnight, quoted above, were obtained with values of the Kp index between 0 and 3, representing rather quiet condition of geomagnetic activity. In order to provide significant new information the flight Nike Apache 14.439 is to be made when the kp index is at least 4, but preferably 5. A higher number, on the scale of 0 to 9, is unlikely at this period of the solar cycle. Since solar activity tends to recur at 27-day intervals it is possible to project a favorable period several weeks ahead. However, individual days may vary widely and it is not possible to anticipate the required conditions precisely. Accordingly, in order to minimize the time that personnel of GCA Technology Division and the University of Illinois will be waiting at Wallops Island, an unusual method of operation is to be tried. The geophysical activity will be monitored at the University of Illinois with data supplied from several sources, principally the Fredericsborg Geomagnetic Center and the Space Environmental Service Center. When the development of a favorable situation is indicated the Wallops Station will be alerted for a launch at midnight of the following day i.e. about 32 hours (minimum) later. This will allow ample time for other personnel to travel to Wallops Island and prepare the payload for launch. The actual launch time is specified as 1230 EDT i.e. 30 minutes before local midnight. The launch window is one hour. The earliest launch date is 6 September 1971.

The payload for this launch is being modified in the following ways:

(a) A new section for the propagation experiment is being assembled for frequencies of 2225 and 3385 kHz;

(b) The geiger counter (2 mil Beryllium window) is being replaced by one of larger aperture (0.5 inch diameter instead of 0.2 inch diameter) and no slit plate is used;

(c) The solar UV experiment is removed and replaced by a blank deck;

(d) The solar aspect sensor is removed;

(e) SCO's are removed for IRIG Channels 12, 14 and 19; the assignment of the remaining channels is given in Table 1.

The payload is to be tested at Wallops Island starting on 22 August 1972. Mating with the vehicle is planned for 28 August in anticipation of horizontal and vertical checks on 29 August. The payload will then be stored in the blockhouse until the launch date is decided.

Cooperating in the launch are L. C. Hale, Penn. State University, with a Super-Areas instrumented to measure positive and negative ion conductivity in the D region and J. Rowe, Arecibo Ionospheric Observatory, who will use the incoherent scatter radar to observe the electron density profile.

TABLE 1: NIKE APACHE 14.439, REVISED TM CHANNEL ASSIGNMENTS

IRIG CHANNEL	SIGNAL
20	Geiger counter (electrons >70 keV)
18	Receiver #1 (2225kHz), modulation
17	Receiver #2 (3385kHz), modulation
16	Probe, log
15	Probe, linear
13	Magnetic aspect and door release monitor
11	Receiver #1, AGC
10	Receiver #2, AGC

IV. FUTURE PLANS

The investigation of the winter anomaly in the D region is to be resumed in the period 27 November to 15 December 1972. Three payloads, Type A Mod. 7, are being prepared for this series of Nike Apache launches. The principal experiments will be the same as those flown in Nike Apache 14.440. The probe linear output will not be telemetered, although it will be available for monitoring on the blackhouse console on the channel 20 position. The telemetry channels have been assigned as shown in Table 2. No experiment to measure atomic oxygen, such as that prepared for the proceding series, is available for these launches. Payload testing is expected to begin at Wallops Island no later than 7 November 1972.

The three vehicles will be launched at noon on days meeting the criteria for each of three types, designated L, H1 and H2. [See previous reports for definitions.] The partial reflection sounder will again be moved from the University of Illinois to Wallops Island for the three-week period of the investigation. It will again be the principal monitor of the ionosphere with respect to determining the type of day. It is hoped that the vertical incidence absorption at 1.8 MHz will be measured at NASA/GSFC.

Other experiments with rocket and/or ground-based experiments will be encouraged to participate in this investigation.

The other two payloads being built are Type B Mod. 4. The boom probe experiment has not yet been defined. These payloads are tentatively

TABLE 2: WINTER ANOMALY SERIES 1972-3, TM CHANNEL ASSIGNMENTS

IRIG CHANNEL	SIGNAL
19	Geiger counter (1-8Å x-rays; electrons >70keV)
18	Receiver #1 (2225kHz), modulation
17	Receiver #2 (5040kHz), modulation
16	Solar aspect and door release monitor
15	Probe, log
14	UV, high gain
13	Magnetic aspect
12	UV, low gain
11	Receiver #1, AGC
10	Receiver #2, AGC

assigned to an investigation of sporadic-E and the nighttime E region. This would be part of a series of launches, particularly including wind measurements, that is being organized by AFCRL. It is designated Project ALADDIN and is scheduled for Wallops Island, no earlier than August 1973.

APPENDIX E

I. INTRODUCTION

The effort during this reporting period has involved the launch of Nike Apache 14.439 on the night of 1 November 1972 and the continued fabrication and testing of the five payloads for Nike Apache rockets.

The efforts involved in testing and firing the Nike Apache 14.439 and the results of a preliminary examination of the data are discussed in the following section.

The status of the three A type payloads, designated Nike Apache 14.509, 14.510, and 14.511 during the reporting period, is discussed in Section III. As noted in the previous Combined Report (1 May - 31 July 1972), these payloads have been assigned to the continuation of the Winter Anomaly operations at Wallops Island and are currently scheduled for firing in December 1972.

The status of the additional two Type B Mod. 4 payloads committed to an investigation of sporadic E at Wallops Island no earlier than August 1973 is discussed in Section IV.

II. NIKE APACHE 14.439

As discussed in the previous Combined Report, the 14.439 payload was taken to the Wallops Island launch site for vibration and testing on 22 August 1972 by J. Pintal and L. Johnson of GCA. Upon successful completion of the test cycle on 31 August 1972, the payload was stored in Blockhouse 2.

One of the outstanding problems of the lower ionosphere at middle and low latitudes is the role of energetic electrons as a source of ionization. This is particularly important at night with the UV and X-ray fluxes are small. This rocket flight was planned to investigate the role of energetic electrons under disturbed magnetic conditions.

The launch time for the rocket was selected to be within 30 minutes of local midnight. This is because of the low electron densities in the E region that have been observed on previous rocket firings from Wallops Island at midnight under quiet and slightly disturbed magnetic conditions.

The launch criterion was specified for a K_p index of five or greater. This is relatively rare at this time in the solar cycle and it was expected that suitable conditions would occur about once each month. A disturbance of this magnitude often lasts for two days. It was planned that the rocket would be set up at Wallops Island so that it could be launched on about 30 hours notice. Daily contact was established with the Space Environment Services Center, Boulder.

The launch period began on 6 September 1972 and the first suitable condition occurred on the night of 13 September 1972: K_p reached a maximum value of 8. It had not been forecast and no attempt was made to launch the rocket.

The next suitable occasion followed a Sudden Commencement at 1655 UT on 31 October 1972. The rocket was launched at 0003 EST on 1 November 1972. The K_p index was 6 at launch time. Preliminary examination of the data indicates a successful flight and the detection of energetic electrons.

In conjunction with the Nike Apache, Super Arcas 15.94 was launched at 0157 EST. This carried an experiment to measure positive and negative ion mobilities and densities by the blunt probe technique. This also was successful.

The Arecibo Ionospheric Observatory was operated in support of the rocket flight. Using incoherent scatter, the electron density profile was obtained. The comparison of the E region profiles at Wallops Island and Arecibo, Puerto Rico, should show the latitude variation of this phenomenon.

The operation was successful both in obtaining the scientific data and in demonstrating the feasibility of this method of operation. At present, it is planned to reduce and analyze the resultant experimental data after Dr. Smith has had an opportunity to perform a preliminary evaluation at the University of Illinois.

III. WINTER ANOMALY SERIES

The three Nike Apache payloads involved in the winter anomaly D region experiment are Type A Mod. 7 and have been designated payloads 14.509, 14.510 and 14.511. During the current reporting period the mechanical and electrical fabrication was completed. The payloads were scheduled for testing and vibration at Wallops Island, Virginia during November 1972.

The three payloads are scheduled for launch in December 1972 at noon on days fulfilling the L, H, and H_2 criteria described in greater detail in previous reports. The University of Illinois partial reflection sounder will again be employed as the principal determinant of ionospheric conditions. It is anticipated that the resultant data will be reduced and analyzed subsequent to preliminary analysis by Dr. Smith.

IV. ADDITIONAL B PAYLOADS

Two additional Type B Mod. 4 payloads are in the process of fabrication. At present, the major portion of the mechanical construction has been completed and it is anticipated that the required electrical wiring and assembly of the payloads will be completed during January 1973. As a consequence, the GCA laboratory testing phase will probably be completed in February 1973 prior to initiating the Wallops Island vibration and testing program. These payloads are expected to be launched no earlier than August 1973 under a subsequent contractual program.

APPENDIX F

I. INTRODUCTION

The effort during this reporting period involved delivery of three type A payloads designated 14.509, 14.510 and 14.511 to Wallops Island, and the participation in the successful launching of payloads 14.509 and 14.510. These events are more fully described in Section II.

The status of fabrication of two type B Mod 4 payloads is covered in Section III. These payloads are scheduled to fly from Wallops Island sometime later than August 1973.

II. TYPE A PAYLOAD

Three Type A payloads designated 14.509, 14.510 and 14.511 were taken to Wallops Island during the period 5 November to 15 November. A Mission Ready review meeting was held at Wallops Island on 20 November when all three payloads were accepted for launch, with the provision that one of the VCO units for the 14.511 payload be subjected to a vibration test. This test was completed on 26 November and the total payload accepted for flight.

Payload 14.509 was successfully launched into an "L" day on 5 December 1972. "Quick look" telemetry data indicated a strong signal from lift-off to loss of signal, which occurred at T + 6 min. 58 seconds.

Payload 14.510 was successfully launched into an "H_1" day on 16 January 1973. "Quick look" data indicated that the rocket under performed, but the scientific objectives were satisfied. A strong telemetry signal was received from T + 27 seconds to loss of signal at 6 min. 31 seconds. The delay in telemetry was caused by a loss of transmission at T + 2 seconds, until the barometric switch activated at 40,000 ft. resuming transmission.

III. TYPE B MOD 4 PAYLOADS

The schedule for the completion of manufacture of two 'B' Mod 4 payloads was changed to 30 April 1973 as per modification order NASW-1994 dated 4 January 1973. In accordance with this change, the following work was accomplished during the subject reporting period.

1) All materials for the two payloads were ordered.
2) Wiring has been completed on the following items:
   - a) D.C. Probe Experiment
   - b) Magnetometer Deck
   - c) Battery Deck
   - d) Barometric Switch
   - e) Transmitter Deck
   - f) V.C.O. Deck

The above items now await inspection, testing, potting and final test.

APPENDIX G

I. INTRODUCTION

The hardware effort during this reporting period involved: (1) the completion of fabrication and testing of two Type B Mod 4 payloads designated 14.513 and 14.514, (2) providing these payloads to the University of Illinois for further testing and integration with experiments, (3) support of pre-flight testing of these two payloads at Wallops Island, Virginia, and (4) support for the Mission Ready Review meeting on 16 July 1973 which terminated GCA's activity on the program.

Further work involved the reduction of data from the following flights:

14.439
14.509
14.510
14.394

II. FABRICATION AND TESTING

Fabrication of the following items was completed for each payload:

(a) Solar aspect sensor
(b) Timer deck
(c) Antennas
(d) Main rails
(e) Converter deck
(f) Guilotine deck
(g) Door release mechanism

The following items were pre-pot tested, potted and them completed final test:

(a) Magnetometer deck(s)
(b) Control deck (including main rail)
(c) VCO deck
(d) Transmitter deck
(e) Timer deck
(f) Antenna
(g) Converter deck
(h) Solar aspect sensor
(i) Battery deck
(j) Differential absorption assembly

The two payloads 14.513 and 14.514 were then final assembled and underwent final system testing.

The two payloads were provided to the University of Illinois on 4 May 1973. At this time both payloads were subjected to a complete system test.

III. LAUNCH READINESS

Support for pre-launch testing was provided by two GCA personnel in residence at Wallops Island from July 2, 1973 to July 16, 1973. During this period of time, both payloads were subjected to pre-environmental testing which included a complete functional and telemetry checkout. The environmental tests consisted of the standard sine wave and random vibration tests followed by a modified acceleration test during which the boom deployment was checked. Both payloads were then subjected to functional checks to verify the successful completion of the environmental tests. Having satisfied all requirements, the payloads were accepted for flight.

Since the two payloads accepted completed the series of payloads being produced by GCA, all the remaining equipment accountable to the contract and held by GCA, was turned over to the University of Illinois representative, Mr. L. Johnson.

IV. DATA REDUCTION

Probe data from four flights were processed during this reporting period. The flight numbers and other pertinent information are listed in Table 1.

TABLE 1

PROBE DATA

Flight No.	14.439	14.509	14.510	14.394
Date*	1 Nov. 1972	5 Dec. 1972	16 Jan. 1973	12 Sep. 1969
Launch Time*	0503:00	1730:00	1730:00	0406:00
Probe Data Starts*	0503:55	1730:44	1730:47	0407:00
Probe Data Ends*	0509:30	1730:33	1735:56	0412:15
*Times and dates are given in Universal Time.				

For each flight the ASTRODATA program (at AVCO, Wilmington, Mass.) was utilized to obtain the probe data in digital form from the original analog data. The sampling rate in all cases was 1 kHz. The processed data were printed out at intervals of 0.1 second. Some difficulty was encountered with the analog tape for flight 14.509 because of a defective time code. The defect was caused by a hardware malfunction at the mobile monitoring station. This defect was reported and the malfunction was corrected.

Reduced data from each flight was forwarded to Dr. L. Smith, University of Illinois as completed, the final data was sent on April 15, 1973.